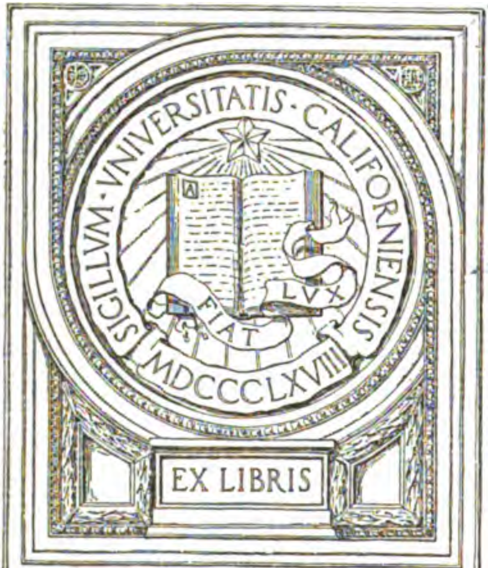
LUTHER BURBANK

HIS LIFE AND WORK

BY HENRY SMITH WILLIAMS, M.D. LL.D.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LUTHER BURBANK

GATHERING POPPIES.

The selected varieties of red oriental poppies blossom early and late at Sebastopol. This piclure was taken in March, 1914, not long after Mr. Burbank's sixty-fifth birthday. It is an excellent portrait of the plant developer as he is to-day.

LUTHER BURBANK

HIS LIFE AND WORK

By

HENRY SMITH WILLIAMS, M.D., LL.D.

AUTHOR OF "MODERN WARFARE," "ADDING YEARS TO YOUR LIFE";
EDITOR IN CHIEF OF THE LUTHER BURBANK SOCIETY

ILLUSTRATIONS IN COLORS AND BLACK AND
WHITE FROM PHOTOGRAPHS

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INTRODUCTION

EVERYONE knows that marvelous work in developing new forms of plant life has been performed by Luther Burbank at Santa Rosa, California. Indeed, the name Burbank is a household word. And yet when you come to question people as to their precise knowledge of what Mr. Burbank has done, you find that, as a rule, their information is singularly vague. They may have heard of the Burbank potato, the stoneless plum, the Shasta daisy, the white blackberry, or the spineless cactus. But something like this is pretty sure to be the full measure of their knowledge as to the Santa Rosa experimenter's specific accomplishments.

This is not strange, for until recently there has been no authoritative and comprehensive account of just what Mr. Burbank has really done, much less how he does it.

Now, to be sure, Mr. Burbank's own account of his lifework is available in twelve large volumes with more than twelve hundred illustrations, all in color. There is no longer any reason why the critic should be in doubt as to just what Mr. Burbank has done, just what are his theories and methods. But of course not everyone has yet seen the comprehensive work in question, so it still seems desirable to give a briefer account of the methods and results of the Santa Rosa experimenter. This is done in the present volume, which, obviously, makes no pretense to compete with the series of volumes just referred to, as issued by the Luther Burbank Society; but which might rather be considered as preliminary or supplementary to those volumes.

Some readers of these pages, I trust, will be stimulated to seek at first hand the pages of the larger work, to read extensive accounts of things that are necessarily treated here with brevity or barely referred to.

And, on the other hand, it is not unlikely that some possessors of the larger work may find the present volume a convenient summary, serving the purposes of recapitulation.

It should perhaps be explained that Mr. Burbank is in no wise responsible for the present book, except in the sense that his work furnished the foundation for it. Mr. Burbank must not be held responsible for any theories or statements herein made, unless particularly accredited to him. But, as evidencing the authenticity of the main presentation of his theories and the chief summary of his work here presented, it is permissible to recall that the writer has acted as editor-in-chief of the series of volumes above referred to, and that in that capacity he has had access to all Mr. Burbank's original manuscripts and records, in addition to spending several weeks in close personal communion with the plant developer himself at Santa Rosa, every aspect of his work being the subject of detailed and elaborate discussion.

The illustrations of the series of volumes issued by the Luther Burbank Society—bearing title "Luther Burbank: His Methods and Discoveries and Their Practical Application"—constitute probably the most remarkable set of color pictures ever published in connection with any single work dealing with plant life. They are 1260 in number, reproduced in the main from direct color photographs made on Lumière plates; and they show every aspect of Mr. Burbank's work, and typical specimens of his achievements in plant development.

We are permitted to reproduce eight of these pictures in the present volume, through courtesy of the Luther Burbank Society. A glance at these will give the reader some intimation of the sumptuousness of the almost endlessly varied mass of color illustrations from which these are excerpted.

The black-and-white illustrations of the present volume are partly from other photographs belonging to the Luther Burbank Society, and partly from original photographs by the author, who has perhaps put Mr. Burbank's unfailing good humor to severer test by his persistent use of the camera at Santa Rosa and Sebastopol than it was ever otherwise similarly tested. For the famous experimenter is a very modest man, and the sight of a camera fills him with trepidation. Fortunately, however, he is as accommodating as he is modest, and as the writer was given permission to make snapshots quite without restriction, we are able to present unique views of Mr. Burbank in action—views that will be highly appreciated by plant lovers who have not been privileged to visit Santa Rosa in person, and to whom the personality of the famous experimenter is the subject of legitimate interest.

It will be seen that the subject-matter of the present volume is divided into three parts: the first dealing with the life and personality of Mr. Burbank, and with an outline of his theories; the second with a detailed treatment of his practical methods as applied in orchard and garden and field and forest; and the third with an attempt to interpret his work in its possible application to what he has picturesquely spoken of as the breeding of the human plant. The last-named subject carries us somewhat afield from Mr. Burbank's direct activities, but it deals with matters of obvious importance, and matters in which Mr. Burbank himself takes the keenest interest. It should be added that the chief part of the matter included in this concluding section of the present work has appeared as a series of monographs issued by the Luther Burbank Society (distributed to its members only), and is reproduced here by courtesy of that organization.

LUTHER BURBANK

PART I

LUTHER BURBANK THE MAN, AND AN OUTLINE OF HIS METHODS

CHAPTER I

LUTHER BURBANK: THE MAN AND HIS WORK

WE naturally think of Luther Burbank as a Californian; but in point of fact the celebrated plant experimenter was born and reared in Massachusetts. The little town of Chester was his birthplace, and he grew to maturity on his father's farm in daily contact with nature in her somewhat primitive aspects.

Mr. Burbank has himself called attention, not without amusement, to the fact that he was his father's thirteenth child; and he has used this fact to give whimsical support to his own familiar method of "quantity production" in plant breeding, pointing out that no one of the first dozen children of his fraternity showed any particular propensity to devote attention to plant development, and drawing therefrom the serious conclusion that the full potentialities of any hereditary strain cannot be realized unless the old-fashioned custom of having large families is practiced.

It is a moral worth giving sober attention, in these days when the Colonial stock, of which Mr. Burbank himself furnishes a rather typical example, is relatively dwindling, to the detriment—at least so some of us think—of our civilization.

Luther Burbank was a rather frail child, though not without abounding physical vigor. He was of a thoughtful, studious bent of mind, with an inherent love of flowers and plants that manifested itself at a very early age, and with an almost equally striking fondness for mechanics. It is recorded that one of his most fondly prized toys in infancy was a specimen of spineless cactus, and that the possession of a flower would almost always quiet him and give him, seemingly, greater pleasure than he derived from any other kind of toy.

His inventive bent manifested itself very early, and led him to the devising of many mechanisms, including a home-made steam engine, which he used to propel a boat, producing thus a prototype of the modern motor boat half a century before that craft gained popularity.

The most conspicuous application of young Burbank's mechanical genius, however, was made in a factory where he went to work just as he was verging on maturity. This was a labor-saving device of such usefulness that it enabled him to multiply the efficiency of his work tenfold, so that his earnings, which at first had amounted to only fifty cents a day, quickly mounted to a really respectable figure. He might have remained indefinitely in the factory, with the assurance of a good salary; but the confinement proved unhealthful, and he soon returned to the fields, never thereafter to leave them.

THE MAN AND HIS WORK

LUTHER BURBANK'S EARLY EXPERIMENTS

The inventive genius hitherto applied to mechanical apparatus was now transferred to the living plant, and from the outset young Burbank began experimenting along new lines even in carrying out the most commonplace work of the gardener. For instance, he found a way to force the development of his sweet corn by sprouting the seed in a hotbed and dropping the young plants into hills in the open as if they were mere seed kernels; and he performed a great variety of interesting experiments in the cross-fertilization of different races of beans, of sweet corn, and of various other garden products.

Nothing strikingly notable came of this work, however, until an occasion when the experimenter discovered a seed ball on the vine of an Early Rose potato; saved the twenty-three seeds that the ball contained, and grew from each of them a hill of potatoes next season. The twenty-three hills were in a single row, and were given precisely the same attention, yet each produced a quite different type of tuber; and one of the hills revealed a large cluster of potatoes of such exceptional size and smoothness of contour and quality of flesh as to be very notable.

This was the potato which the young experimenter sold next season to a practical gardener, who gave it the name of the Burbank potato.

It was estimated several years ago by the authorities of the Department of Agriculture at

Washington that more than seventeen million dollars' worth of Burbank potatoes had been raised in the United States since the variety was introduced. The producer himself received only one hundred and fifty dollars for his prize. The money sufficed, however, to pay his fare across the continent, and enabled him to carry out his ambition to migrate to a climate better suited to the purposes of the plant developer,—for he had long since determined to give his life to this work.

THE MIGRATION TO CALIFORNIA

Arriving in California, Mr. Burbank selected Santa Rosa as his residence, and this has continued to be the seat of his activities to this day.

The migration was made in the year 1875. At that time the potentialities of California as a fruit-growing state were not very fully realized, and it was by no means easy for a young man without capital to establish himself in the practical business of a nurseryman, which was Luther Burbank's immediate ambition. Before he could carry out this ambition, it was necessary to serve an apprenticeship of two or three years, during which he turned his hand to any work which presented itself. He developed skill as a carpenter, and he continued to earn a living at that trade for some time after he had established a nursery by way of avocation.

Those were trying years; but Yankee thrift, energy, and perseverance finally prevailed over all obstacles and within four or five years after coming to California Mr. Burbank found himself in possession of a commercial nursery that netted him an annual income of about ten thousand dollars. His orchard products were mostly of standard varieties, but he had applied to them from the outset the selective skill that was to make him famous, and he had gained for his seedlings a reputation for reliability that caused them to be bought by would-be orchardists throughout the fruit-growing region.

Such commercial success as this was gratifying, but Mr. Burbank regarded it as only a stepping-stone. Even while his chief time was necessarily given over to the practical duties of the nurseryman, he found opportunity to make numberless experiments in hybridization and selection among the various plants in his nursery; and so soon as his financial affairs gave the least promise of security, he had cast about for a piece of land on which he could establish an experiment garden to be devoted exclusively to the production of new and improved varieties of plants of every type.

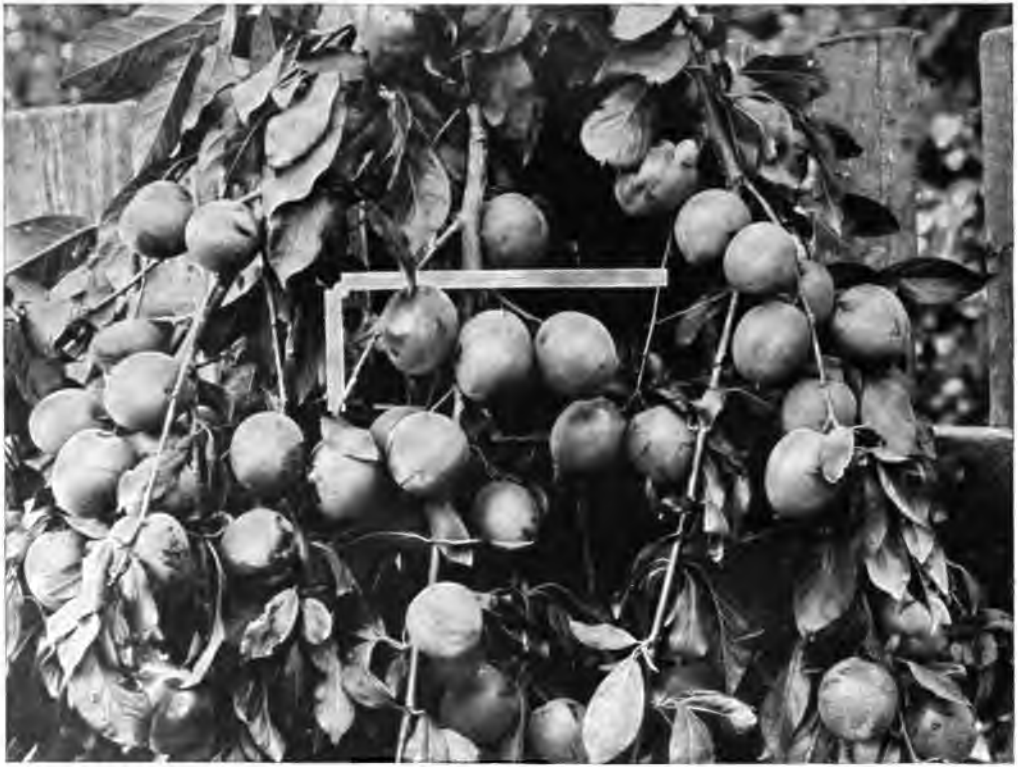
He found four acres that could be made available by proper drainage and fertilization, in the town of Santa Rosa, and there he established the garden that was soon to be famous as the seat of the most remarkable series of plant experiments that have been carried out in our generation. A little later he purchased a tract of eighteen acres at Sebastopol, seven miles away, where the topographical and climatic conditions were slightly different. There his main experiment orchards were established, and opportunity was afforded for the carrying out of the idea of "quantity production" more effectively than was possible in the restricted area of the Santa Rosa garden.

From that day to this, Mr. Burbank has conducted his experiments on these two plots of land, aggregating about twenty-two acres. Within this relatively small area more than a hundred thousand distinct experiments have been carried out, involving five or six thousand species of plants, and numberless varieties, the original seeds or stocks or roots of which have been sent to Mr. Burbank from all parts of the world.

Probably there is no other similar area of the earth's surface that has seen a corresponding variety of vegetable products in the same time; certainly there is no other that in our day has produced such a galaxy of new and wonderful plant products as have grown in the experiment gardens at Santa Rosa and Sebastopol.

NEW APPLICATION OF OLD METHODS

The fundamental principles of plant development through which Mr. Burbank thought to develop new and improved varieties were not in themselves novel or revolutionary. They consisted essentially in the careful selection among a mass of plants of any individual that showed exceptional qualities of a desirable type; the saving of seed of this exceptional individual, and the



A CLUSTER OF BURBANK PLUMS

This is the Maynard plum, one among the more than sixty new varieties of plums that Mr. Burbank has developed.

carrying out of the same process of selection among the progeny through successive generations.

Couple this method of selection and so-called line breeding with the method of cross-pollenizing different varieties or species, to produce hybrid forms showing a tendency to greater variation or to the accentuation of desired characters, and we have in outline the fundamental principles of plant breeding as known to horticulturists for generations, and as applied by Mr. Burbank from the outset of his career. But there were sundry highly essential details of modification that were introduced by the Santa Rosa experimenter, as will appear presently.

Moreover, even in the application of the old familiar method, Mr. Burbank was able from the outset to gain exceptional results because of certain inherent qualities that peculiarly fitted him for the work. Among these qualities was his exceedingly acute vision, a remarkable color sense, and almost abnormally developed senses of smell and taste. Artists who have tested his eyes have declared that he can readily detect gradations of color that to the ordinary eye show no differentiation whatever; and it is a matter of hourly demonstration that he can ferret out an individual flower having any infinitesimally modified odor in the midst of a bed of thousands of such plants, almost as a hunting dog detects the location of a grouse or partridge under cover.

Similarly his exquisitely refined sense of taste guides him in selecting among thousands of individual plums or cherries or grapes or apples or berries the one individual specimen that has the most delectable flavor or that shows a minute modification of flavor in the direction in which he is endeavoring to modify the variety.

This almost preternatural endowment of special senses is supplemented by a knowledge of the coordination of parts—say between the stem or leaf and the future fruit of a plant—that is so penetrating and mystifying as to seem intuitional and to suggest occult powers of divination.

As an instance, you may see Mr. Burbank striding along a row of, let us say, plum seedlings comprising some thousands of plants perhaps a foot high. He seems to inspect the little trees but casually, except that now and again he pauses for a moment to indicate with a motion of his hand that this or that plant has particularly attracted his attention. A helper, or more likely two helpers—for one can scarcely keep up with the energetic leader—will be at hand to note the signals; and a bit of white cloth will be tied about each successively selected seedling; or two pieces of cloth, or even three, in case an individual has seemed to show quite exceptional promise.

And with that, one stage of the work of selection is finished. Perhaps ten thousand seedlings have been passed in review in a half-hour, and conceivably fifty or a hundred have been selected for preservation. These have shown to the keen scrutiny of the plant experimenter such qualities of stem and bud and leaf as to forecast the type of fruit sought to be developed in this particular experiment.

The entire rows of seedlings are the product of hybridizing experiments and antecedent selection extending perhaps through many generations. The seed from which they were grown has been carefully gathered and treasured, and infinite pains have been taken to bring the seedlings, through transplantation and cultivation, to their present stage of development.

Yet now, in a single half-hour, they have been made to run the gauntlet of a vision that seems to penetrate to the very heart of their germ-plasm, like an X-ray, and all but a bare half-dozen or so in each thousand have been found wanting. Another hour, and the ten thousand failures—less the half-hundred—will have been uprooted and piled in a heap to be burned like any other mass of rubbish. They had done their best, but their best was not good enough; and the soil that they occupied must be given over to some other line of experiments; for every acre of these gardens must be made to do the work of a score of acres.

Meantime the dozen or score of selected seedlings that remain as the lone survivors here and there in the devastated ranks will be treasured and be given every horticultural attention. At the proper season they will come under the knife of the grafter, who will cut each stem into appropriate sections and graft pieces on the limbs of some sturdy tree of the same species. This is done to hasten their development, for Mr. Burbank has discovered that stems thus grafted will come to bearing much earlier than if left on their original roots. Time is precious, particularly when we are dealing with plants of such slow growth as the fruit trees, and it is obviously worth while to save a year or two, as is thus possible; for at best an experiment in the development of a new type of fruit must be carried out, as a rule, through a good many generations, making significant encroachments on the working life of the plant experimenter himself.

Where such a method as that just outlined is carried out, it is obvious that everything depends upon the skill with which selection is made. A man lacking Mr. Burbank's "intuitional" skill in such a selection would inevitably go wrong. His experiments would come to nothing. He would inadvertently destroy the best and preserve the worst. By no mathematical chance could he select the right dozen or score of individuals among the tens of thousands.

But that Mr. Burbank is able to make such selections with a correctness that is little less than weird has been demonstrated again and again through tests in which various of the discarded seedlings have been preserved and brought to fruitage for comparison with the selected ones of their fraternity.

Always the selected individuals show more of the quality that is being sought than is shown by the specimens taken from the discard; thus justifying a forecast that was made so readily with such seeming facility as to appear almost necromantic.

In point of fact, the plant experimenter was exercising no occult powers but only trained senses backed by an amazing fund of practical knowledge. He was looking for stems of a particular size and ruggedness of contour; for leaves that were symmetrical, right-hued, and thrifty; for buds that were plump and fat and of just the right color. But his eye took in the details so quickly and his conclusions were reached with such seemingly automatic precision, that the entire procedure took on a mystifying aspect of wizardry.

With such exhibitions of his skill constantly in evidence, it is not strange that Mr. Burbank should have become traditional among his own contemporaries as the "wizard of Santa Rosa"; although the worker himself has always ardently deprecated any such characterization, calling himself a "plant experimenter," and being foremost to affirm that what he accomplishes is done by careful study of the laws of heredity, ceaseless scrutiny of the physical qualities of plants in their every aspect, and the definite application of knowledge gained through thousands of antecedent experiments.

The range and scope of these experiments, it may be added, are no less astounding than the manner in which they are carried out. There is scarcely a tribe of plants showing any promise whatever of development of its stock or root or flower or fruit and having the remotest prospect of thriving under the climatic conditions of Santa Rosa and Sebastopol that has not been tested by specimens brought from one corner or another of the world—from both hemispheres and from every continent—and set to work in Mr. Burbank's training school. To give the names of the different species and varieties that have here been modified and improved through selective breeding—quite overlooking the other legions that have proved recalcitrant—would require many pages. So I must be content with the citation of only a few of the more conspicuous examples.

NEW FRUITS FOR ORCHARD AND GARDEN

Consider, for example, the orchard fruits. Mr. Burbank has produced almost numberless new varieties of apples, pears, peaches, apricots, plums, prunes, cherries, and quinces. He has introduced more than sixty new varieties of plums and prunes, combining the strains of ancestors from Europe and Japan with those of our native species, and producing an extraordinary company of fruits of the most varied qualities.

Here, for example, are prunes that are not only of gigantic size and borne in profusion, but which have a quality of ripening in midsummer and of developing a greatly increased sugar content. Here are plums that add to their other qualities the capacity to withstand shipment across the continent, or for that matter round the world. Here is one plum that looks and tastes like an apple and another that has precisely the quality of a Bartlett pear. And here are plums and prunes that while exteriorly looking like other fine specimens of their kind differ essentially from all others in that you could bite right through them as you bite through a strawberry, because they are stoneless.

And then, most marvelous of all, here is a fruit that had a plum for one of its ancestors, but for another ancestor an apricot; a strange hybrid which, in recognition of its origin, was named the "plumcot" and which constitutes a brand-new type of orchard fruit, the first addition that has been made to the familiar list within historical times, and the only orchard fruit whose origin is definitely known. This one was created at Sebastopol, as the result of a long series of tests in cross-pollenizing the plum and apricot; tests which at first seemed doomed to failure, but which ultimately culminated in the production of a wonderful new fruit.

In the small-fruit garden, Mr. Burbank has developed many highly interesting new forms, some of which are entitled to rank as new species. There is, for example, the Primus berry, a cross between the dewberry and the Siberian raspberry; the Phenomenal berry, a cross between the dewberry and the Cuthbert raspberry; and the Paradox, a cross between the Lawton blackberry and the crystal white blackberry.

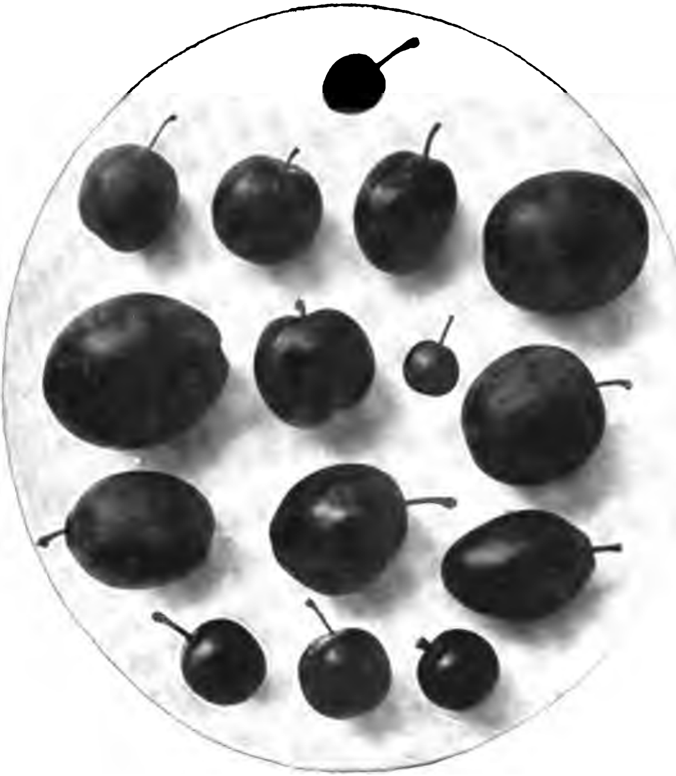
Then there are luscious blackberries that are pure white, and others that grow on vines that are as free from thorns as the twigs of an apple tree.

Also there is the sunberry, a palatable fruit produced by combining the traits of two inedible nightshades, and there are numerous new varieties of strawberries, huckleberries, currants, gooseberries, and elderberries, as well as sundry rare exotics that will claim our attention in due course.

NEW VEGETABLES AND FLOWERS

In the vegetable garden, Mr. Burbank achieved his earliest success through the production of the Burbank potato, the full story of which will be told presently. He has worked effectively with all the familiar types of garden vegetables, his efforts culminating, perhaps, in the development of the now celebrated Crimson winter rhubarb, the ancestor of which came from New Zealand.

Among thousands of experiments with flowers it is hard to choose, so many and so notable are the developments. The Shasta daisy, which combines the strains of species from Europe, from Japan, and from America, has exceptional interest both from a scientific and from a popular standpoint. But scarcely less interesting are the hybridizing experiments through which were produced the giant amaryllis with its nearly twelve-inch blossom, the spectacular tigridias, the scented callas, dahlias, and verbenas, the beautiful wat-



A GROUP OF STONELESS PLUMS

The original from which Mr. Burbank's numerous stoneless plums developed, is a European fruit no larger than the smallest of the above specimens. The picture illustrates the variation among seedlings, and the remarkable development in size of the better varieties, brought about through cross-breeding. There is a corresponding improvement in the quality of the fruit.

sonias and gladioli, the wonderfully varied poppies, including one that is blue in color, and the extraordinary colony of lilies showing thousands of new and strange combinations of form and color.

By way of adorning lawn and park, Mr. Burbank has developed a substitute for grass in the South American lippia which thrives in time of drought, and requires not one-tenth the attention given ordinary lawn grass. He has developed a vast number of ornamental shrubs and vines, including new types of clematis with beautiful and varied flowers. And in experimenting with trees he has produced walnuts that grow to gigantic size in a few years, and, at the other end of the scale, chestnuts that bear abundant crops when they are mere bushes.

A chestnut that bears large nuts at six months from the seed creates as much astonishment as almost any other single anomaly seen at the famous experiment gardens at Sebastopol.

The chestnut that is developing a smooth burr is also of peculiar interest; matching the walnut that was made to bear so thin a shell that the birds destroyed the nuts, so that it became necessary to thicken the shell by further selective breeding.

These glimpses, together with bare mention of the spineless cactus with its amazing crop of luscious fruit, must suffice to suggest the varied lines of plant experiment that Mr. Burbank carries forward year by year.

We shall have occasion to inquire just how some of these extraordinary anomalies in plant life were produced in the course of our examination of the special theories of plant development that have guided Mr. Burbank in his elaborate and fruitful experiments; and fuller details will be given in the chapters making up Part II of the present volume.

BURBANK METHODS AND THE HUMAN PLANT

A man of Mr. Burbank's philosophical cast of mind could not fail to give a vast deal of thought, first and last, to the question of a possible application of knowledge gained in the experiment garden to better development of the human race. In point of fact, Mr. Burbank has not only thought but has written and talked on the subject very extensively. He has very pronounced ideas about the development of the human plant that are the outgrowth of his experimental studies with plant life.

Nowadays we all understand that the same general principles apply to all types of living creatures. With the proper allowance for details of variation, the laws of heredity studied in the vegetable garden can be applied with much assurance to the breeding of animals or the betterment of the human race itself. So large a subject cries out for extended treatment, but it is obvious that in the space available here I can do no more than make brief reference to the possible application of the principles of plant breeding, as Mr. Burbank interprets them to the human race.

At the very outset, we are met with obvious difficulties. Mr. Burbank selected only good stock from which to breed. He saves ten or a dozen plants from a bed of thousands and tens of thousands. Obviously no such restriction is possible in the human family, even were we to put into effect the most sweeping conceptions of the eugenist.

But Mr. Burbank optimistically calls attention to the fact that the civilized races of to-day are in effect highly selected stock. They are the result of many centuries of breeding during which society endeavored to rid itself of undesirables. Capital punishment for minor crimes doubtless had an appreciable eugenic influence; and under the pampering conditions of city life, disease decimates the ranks of the weaklings; even wars tend on the whole to remove individuals of less evolved mentality.

So, on the whole, such a stock as the average American race is a highly evolved and selected type, in large measure adapted to its environment, and eminently fit for propagating the species.

But of course some members are better fitted than others to carry out this function; and at present there is an unfortunate tendency for the better members to have small families while the less desirable ones have large families. It perhaps does not need the advice of the Santa Rosa experimenter to tell us that this propensity, if not checked, must lead to disaster, but his experience may be cited as emphasizing the lesson.

Unless the more desirable members of a race can be made at least as prolific as the less desirable ones, that race must deteriorate.

In this connection, the enormous immigration of recent years, made up largely of individuals of a less evolved type (as illustrated by the fact that thirty-five per cent of the membership of the "new immigration" cannot read or write), becomes a possible menace. Twenty-seven million immigrants have come to us since 1860—that is to say, during two generations. Mr. Burbank feels well assured that so large an increment of new blood must directly modify the character of our race; and he is at one with many sociologists in questioning whether the increment of new germ-plasm has been, on the whole, of a type to prove beneficial.

Of course even an illiterate immigrant might bring certain qualities—say a musical or artistic sense—that would be advantageous for blending with American racial strains; somewhat as Mr. Burbank's inferior little French plum had one important quality of stonelessness that made it valuable. But it must be recalled that Mr. Burbank was obliged to instil a preponderant influence from valuable strains of plants to the point of entire elimination of the poor qualities of the original stoneless variety. Without this instillation of good qualities, he could never have produced a stoneless plum having commercial value. Similarly, it will be necessary to overbalance the undesirable qualities of the unevolved immigrant by a preponderance of good blood if we are to make use of his desirable qualities.

From this point of view, then, the same question is emphasized: The better stock of America must be induced to reproduce itself more abundantly than has been its custom of late, or the infusion of immigrant blood of the type that is coming to us will be ultimately harmful.

As to the rearing of the human plant in its early stages—that is to say, the care of the child—Mr. Burbank has ideas that are equally pronounced; and here he is able, perhaps, to make more directly tangible applications of his studies in the field. As a practical horticulturist, he has been called upon thousands of times over to observe that everything depends upon the treatment that the seedling receives the first few days or weeks of its life. He takes infinite pains to provide just the right soil, just the right conditions of moisture and sunlight and shelter from the wind; and he has seen it demonstrated times without number that the weal or woe of the future plant, whatever its heredity, is largely determined by this early treatment.

Making application to the human plant, he believes that few people fully understand how largely the body and mind of the child are molded by the environing influence of infancy. He urges very strenuously that life should be made agreeable for the young child; that it should be kept in the open, allowed to play, to come in contact with nature, to do the things in which childhood naturally delights.

He would have no child sent to school until it is nine or ten years old, believing that the education of the playground and field is better than the education of the schoolroom during this early period.

And when the child has reached the school age, he would have its tasks made less laborious and exacting than they sometimes are.

He would pay heed at all stages to the child's bodily development, knowing that fine blossoms do not come from dwarfed plants.

In a word, he would make the environment of childhood and adolescence healthful and stimulative and pleasure-giving—comparable to the environment that he supplies for his seedling plants. Only by doing as he does can Mr. Burbank secure the best results with his plant protégés; and only by a comparable line of action, in our treatment of the child, so he believes, can we count on making the most of the coming human generation.

Mr. Burbank's love of children is comparable to his love of flowers. It was peculiarly appropriate that the Legislature of California should have set aside his birthday, the ninth of March, as a school holiday to be known as Burbank Day. On that day each successive year the school children of Santa Rosa come to pay their respects to Mr. Burbank in person; and he has received as many as four thousand letters at once congratulating him on the occasion from the school children of other cities and even of distant states.

To see Mr. Burbank on his doorstep surrounded by a group of school children is to see him as happy as when he is in his garden amidst beds of rare and beautiful flowers. No sketch of the Santa Rosa plant developer would be complete that did not refer to this aspect of his interests and give emphasis to this phase of his personality.

In Part III of the present volume we shall have occasion to treat somewhat in detail the question of the possible application of Burbank methods and allied biological data to the improvement of the human plant. But we must first study the methods themselves and their direct application in the gardens of the Santa Rosa experimenter.

CHAPTER II

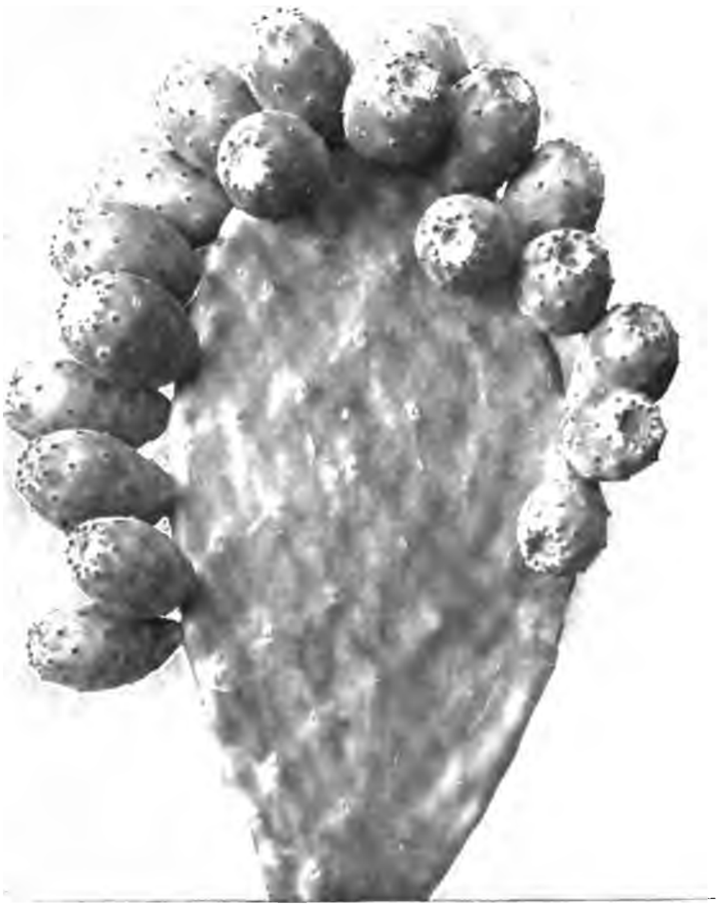
THEORIES OF PLANT DEVELOPMENT

FIRST, last, and all the time Mr. Burbank is a practical plant developer. But it would have been quite out of the question for a man of his energetic and active type of mind to have gone about his experiments without theorizing constantly as to the whys and wherefores of the intricate life forces with which he was dealing.

In point of fact, it is as natural for Mr. Burbank to theorize as it is for him to make practical experiments. His mind is no less incessantly active than his body, and his views on the theories that underlie plant development are as pronounced and radical as are his opinions concerning practical matters of horticulture and plant management in the fields, regarding which, doubtless, he has had a larger personal experience than any other man in the world.

In briefly outlining Mr. Burbank's attitude toward various of the moot points of heredity, it will be convenient to call attention to a few typical instances of his own experiments that give support to his views.

(1) First as to the broad general question of Darwinian evolution. When a very young man Mr. Burbank read with avidity Darwin's then re-



A FRUIT-BEARING SLAB OF SPINELESS CACTUS

The particular slab here shown is merely an average specimen. Numberless slabs in the same field bear two or three times as many individual fruits. A slab has been known to bear as many as 150 of these "Cactus pears."

cently issued work, *Animals and Plants under Domestication,* and at once he began making personal scrutiny of all the plants of his neighborhood, and was struck with the fact of universal variation both in the wild state and under cultivation.

From the outset, his experiments had to do with selection between individual specimens that differ in some measure from their fellows, and at every stage of his work such a selection continues. "The beginning is selection and the end is selection," declares Mr. Burbank; and the possibility of developing new races of many types from a single stock through selection alone has been demonstrated by him thousands of times over.

As Burbankian selection is after all only natural selection, in which a man's wishes become the chief determining agent among environmental influences, it may fairly be said that the demonstrations made over and over at Santa Rosa have supplied the largest body of evidence for the truth of the doctrine of evolution through natural selection that has anywhere been made available.

After studying Mr. Burbank's results, it is impossible to doubt that natural selection has been at least one highly important agency in shaping the evolution of the living races.

As an instance of the way in which new races may be rapidly developed by artificial selection alone, we may cite the case of the half-dozen new varieties of garden peas, differing radically from one another, and each breeding true to its own kind, that were developed by Mr. Burbank in the course of six generations from a single parent form.

The new variety of heuchera, or "wild geranium," with its amazingly corrugated and convoluted leaf, furnishes another example of extraordinary modification of form brought about by merely selecting the seed of an individual that showed a tendency to modification, and carrying on the selection through several successive generations.

That the same principle applies equally to the modification of stalk or root or bulb or flower or fruit of plants of every type has been demonstrated so many times over in Mr. Burbank's experience that to cite his proof of the proposition in its entirety would be equivalent to naming all the hundreds of new varieties that he has developed. For the cases are few indeed in which the principle of selection has not been applied at some stage of the experiment. Even where hybridization has played an important part, it is of course necessary first to select the parents for crossing; and then, in due course, selection is made again among the progeny.

So it may be repeated that artificial selection is the keynote to plant development; and that the experiments at Santa Rosa and Sebastopol furnish an unending series of demonstrations as to the way in which nature works in the bringing about of evolution of races through natural selection and the survival of the fittest.

(2) As to the question of the transmissibility

of acquired characters, Mr. Burbank answers emphatically in the affirmative. As he sees the matter, all traits of every species were at some time acquired in response to environmental stimuli. To deny the transmissibility of new traits thus acquired from time to time in the geological ages would be tantamount to denying evolution itself. He finds that plants of closely related species brought from different continents transmit their qualities when interbred; and he has little patience with the modern quibble which would admit the transmissibility of qualities imprinted directly on the germ-plasm, while denying transmissibility of the changes in the body-plasm, in view of the fact that the germ-plasm itself is part of the plant body and, moreover, is apparently disseminated everywhere throughout the plant organism, inasmuch as individual buds or pieces of stalk, or bits of root or bulb, may in numberless instances reproduce the entire plant quite as effectively as it is reproduced from the seed.

In thus advocating the theory of the universality of acquired traits, however, Mr. Burbank of course does not refer to gross lesions; and it may be added that he has not personally conducted any experiments in the attempted modification of the germ-plasm through use of chemicals or of radium such as some other workers are now undertaking.

(3) As to the origin of the variations observed in nature, which supply the material for the operation of natural selection, Mr. Burbank has very pronounced ideas. He believes that the usual cause of such variation is hybridization between different species or varieties. One of his earliest discoveries was that by crossing divergent races or totally different species he could produce hybrids that were different from either parent, and that sometimes these hybrids breed true.

A striking illustration of this was furnished when he cross-pollenized a raspberry brought from Siberia with a California dewberry—a species of trailing blackberry. The result was a berry of a new type, differing radically from either parent, which seems entitled to rank as a new species, inasmuch as it has its own type.

Another illustration of the production of a new species by hybridizing is found in Mr. Burbank's Phenomenal berry, the product of a union between the Cuthbert raspberry and the California dewberry. Yet others are the plumcot, already referred to; the extraordinary Paradox walnut, which combines the strains of the Persian walnut and the California black walnut; and the Shasta daisy, combining the strains of a European, an American, and a Japanese species, and itself differing very radically from any one of its ancestors.

Mr. Burbank has found many instances of

hybridization in a state of nature. He has, for example, seen hybrid raspberries growing wild and maintaining their own in the same neighborhood with both of their parents. The same thing occurs in the case of a species of madder that grows abundantly along the roadsides near Sebastopol. Mr. Burbank has seen nuts that he believes to be a natural cross between the pecan and hickory. In a word, he believes that hybridization among wild species is an exceedingly common phenomenon, and that this is at least one of the prominent means of developing new species and new varieties upon which natural selection may work differentiation of species.

Mr. Burbank thus supplements and extends the Darwinian theory, offering what seems the best explanation hitherto suggested of the "origin of the fittest," about which Darwin himself and his chief disciples were very much in the dark.

It should be added that Mr. Burbank's experiments, while showing in numberless cases the possibility of the development of new varieties through cross-breeding, show also the limitations that nature puts upon the method by denying fertility to hybrids that result from the crossing of parents too widely divergent. For example, he made an extraordinary series of cross-pollenizing experiments in which the strains of many members of the rose family, including the apple, the pear, the mountain ash, and the rose itself, were blended with those of the blackberry. Similarly he crossed the raspberry and the strawberry, also the pear and the apple, the pear and the quince, and the quince and the apple; and yet again, the petunia and the tobacco, and the crinum and the amaryllis. But in each of these cases, while very interesting hybrids were produced, they were entirely sterile, and the experiment could go no further.

Sometimes species are crossed that are just widely enough divergent so that the offspring are relatively infecund but not actually sterile. Such was the case with the cross between the Persian and the California walnut, the offspring of which is a tree of enormously rapid growth, but bearing only a handful of nuts; whereas another walnut cross, that between the American black walnut of the East and the California black walnut, is enormously prolific, bearing bushels of nuts where the other hybrid bears only individual specimens.

The celebrated cross between the plum and the apricot furnished interesting illustrations of the same thing. Most of the hybrids thus produced bore imperfect flowers lacking petals or stamens or pistils, as the case might be. It was only after many efforts a specimen was produced that was fertile, yet ultimately the race of hybrid plumcots was so developed that it now has many varieties, some of them being excessively prolific. Yet another instance of the way in which the barriers between species may be broken down by persistent effort (through ultimately finding plants having just the right degree of affinity) is that in which Mr. Burbank produced the sunberry by crossing two species of solanum, that he had attempted ineffectually to cross from time to time for twenty-five years, success finally coming in the form of a single fertile seed case.

MENDELIAN HEREDITY

(4) As to later progress of hybrid races. Whereas sometimes, in case of the Primus berry, a hybrid shows a combination of the traits of the parents, constituting a new type that breeds true, this is not the usual result of crossing different species or marked varieties. As a rule, the hybrid shows a tendency, as regards any given character, to follow one parent to the exclusion of the other. If, for example, you can cross a stoneless plum with an ordinary plum, you must expect that all the progeny will bear stone fruit.

But Mr. Burbank early made the discovery that if hybrid forms are allowed to interbreed, their progeny usually show an extraordinary tendency to variation, some of them reverting in one direction and some in another, and some individuals combining the traits of the two divergent lines of ancestry in new combinations. He discovered that the best opportunity was afforded for the development of new types; and he eagerly put this discovery to account in numberless breeding experiments.

Now this discovery, made by Mr. Burbank in the early eighties, is essentially the discovery that had been made twenty years before by Gregor

Mendel, the Austro-Silesian monk, to which no one paid any attention until long afterwards.

After Mendel died in 1884, there was an interval of about sixteen years, prior to his rediscovery and the posthumous promulgation of his doctrines by Professor De Vries and others, during which Mr. Burbank was probably the only man in the world who had any clear conception of the essential facts of the segregation and recombination of characters in the second filial generation of cross-bred races. Mr. Burbank did not make mathematical tests in connection with his experiments, as Mendel had done; but he demonstrated the general truth of what has since come to be known as Mendelian inheritance thousands of times over in the course of his independent experiments at a time when neither he nor anyone else had so much as heard the name of Mendel.

It was by application of his independent discovery of the principle of the segregation and recombination of parental characters in the second and subsequent generations that most of his remarkable new varieties and new species were developed.

Thus the commercial races of stoneless plums and prunes were produced through blending the strains of a little partially stoneless European plum that was not much bigger than a cranberry, and was acrid and worthless, with the strains of numerous choice varieties of cultivated plums through successive generations, each immediate cross resulting in stone fruit; and the quality of

MR. BURBANK INSPECTING A CHOICE VARIETY OF SPINELESS CACTUS

The picture was taken in the season of 1914. The bed of young spineless cactus plants here shown includes some of the most perfect specimens hitherto developed. They grow in the garden at Santa Rosa.

stonelessness, in combination with other desirable qualities from divergent strains, reappearing only in the subsequent generations.

Altogether similar was the history of the thornless blackberry, which finally developed into a wonderfully vigorous plant with stems as smooth as pussy-willows, and bearing an abundance of luscious fruit, is the product of many generations of cross-breeding through which the quality of thornlessness that was inherent in a little otherwise worthless trailing dewberry from Virginia was combined with the good qualities of sundry varieties of cultivated blackberries that grew on thorn-laden bushes.

The development of the white blackberry, from a small variety of brownish-white color to a splendid berry of snowy whiteness, came about in the same way; and to this day, if you were to cross an ordinary blackberry with the Burbank white variety, you must expect that the progeny will bear black berries, and only in the succeeding generation will plants appear that bear the white fruit of one of their grandparents.

SELECTIVE LINE BREEDING

(5) The accentuation of characters by line breeding plays a no less significant part in Mr. Burbank's scheme of plant development. Whether the plant with which you deal be pure breed of a hybrid, it will seldom happen that a quality that you are attempting to develop is manifested

in superlative degree. It may be, indeed, that the desired quality appears only as a faint trace or suggestion.

Such was the case, for example, with a certain specimen of the calla in which Mr. Burbank detected a faint trace of a pleasant perfume. He carefully preserved the seeds of that calla, and by similarly selecting among the descendants he produced a race of perfumed callas. In the same way he produced scented petunias and verbenas that have gained great popularity.

Again, Mr. Burbank once found a specimen of the California poppy that had a faint line of red extending down one of its golden petals. This specimen was transplanted and treasured. Among its progeny was a specimen that showed a slightly more conspicuous red line on a petal of one of its flowers. The seed of this specimen was preserved; and so on generation after generation, the tendency to red being accentuated in a few individuals in each generation; until finally a new variety of poppy had been produced in which the normal golden color had disappeared altogether, and the entire flower was of a bright crimson—justifying the name of "Fireflame" that was given it.

The Santa Rosa Shirley poppy, with its delicately crenated petals; the silver-lining poppy, with the inner surface of its petals transformed from red to white, and the wonderful blue poppy, selected out, through generations of breeding, as the remote descendant of an individual red poppy whose petals showed a trace of cloudiness, are other striking examples of the accentuation of a character through line breeding.

The sturdy winter rhubarb has been developed in the same way from the plant imported from New Zealand with a stem no larger than a pencil. The absolutely smooth cactus is the descendant of plants that only showed a tendency to be somewhat less spiny than their fellows.

CREATION OR RECRUDESCENCE

An interesting question arises as to whether such accentuation of a peculiarity or tendency may amount to the bringing out of a new character that was not represented in any ancestor, near or remote.

Is Mr. Burbank's light blue poppy, for example, the first of its kind; or were there blue flowers among some of the ancestors of the poppy?

The best view appears to be that the seemingly new trait was really submerged in the ancestral germ-plasm, if the phrase be allowed, and has been made tangible by the removal of more or less antagonistic traits that obscured it. In the case of the blue poppy, for example, the submergence was doubtless of long duration, for blue poppies have not been in fashion within the memory of man; but through successive generations of selection the factors for redness and yellowness were removed, and an individual finally produced in which the primal blue, which was probably the color of some very remote ancestral poppy, was revealed. In a crude general way, the process might be compared to the restoration of an ancient canvas by the removal of successive layers of pigment with which it has been overlaid.

THE COLORS OF FLOWERS EXPLAINED

While the colors of flowers are under consideration, it may be well to say a word about a theory as to flower coloration that may sometimes prove helpful in carrying out a line of experiments; the theory, namely, that all flowers were originally green and that as evolution progressed they varied up and down the chromatic scale,—some lines of descent producing successive blue and indigo and violet flowers, while other lines of descent produced yellow and orange and red flowers instead.

If we hold that hereditary factors once acquired by any race are never altogether lost from the germ-plasm of that race, it would follow that all red flowers have the potentialities of orange and yellow in their heredity, and that all violet flowers have the potentialities of indigo and blue.

Moreover, since there would have been cross-breeding at all stages of development, it may fairly be assumed that there are strains of blue as well as of orange and yellow in the red flower; also strains of blue in the yellow flower, and strains of yellow in the red flower.

There is some evidence to show that white flowers may be due to a blending of pigments—say a mixture of yellow and blue. White may also be due to a prismatic effect induced by the presence of air spaces between the cells.

It is fairly clear that different colors may be advantageous for the flower according to the mode of growth of the plant on which the flower is borne. Thus plants that grow in the shadow and those that bloom in the evening advantageously bear white or pale yellow flowers, as these are more conspicuous than the most gaudily hued flower would be under the circumstances. On the other hand, a plant that grows in the open may bear a red flower both because that color will be attractive to insects that fertilize the flower and because the reflection of the long waves of light (giving our eye the impression of red) serves to shield the petals from excessive heat.

If, then, most flowers have the potentialities of wide color variation, there is opportunity for the play of natural selection in adapting each flower to the environment in which the plant on which it grows flourishes to best advantage.

This theory of flower coloration finds a measure of support in another theory which attempts to explain the peculiar phenomena of "dominance" and "recessiveness" as manifested in Mendelian heredity. According to this explanation, where two antagonistic characters thus Mendelize, the one that is dominant is the newer character and the one that is recessive is the older. This precisely reverses the view that has been suggested by some biologists, but there is a large amount of evidence to support it.

To illustrate from the case in point, it appears that, as a rule, when red flowers are crossed with flowers of another color, say white, the red tends to prove dominant. Similarly, when a white poppy is crossed with Mr. Burbank's blue one, the progeny are white. This is consistent, at least, with the theoretical assumption that new characters dominate old ones, and that red is the newest flower color and white a newer color than blue.

I must not claim space to elucidate either theory in detail here. But I may point out, in passing, that the theory that new strains are dominant to older ones aids us sometimes in the interpretation of the observed results of experiments in plant breeding. We should expect, for example, that the spines would be dominant to spinelessness in case of the blackberry and cactus, for it may be assumed that the spines were a comparatively recent development in the evolutionary scale. Again, pigment would be dominant to lack of pigment in the blackberry; for the fact that the young berries are colorless or green strongly supports the assumption that the primordial ancestors of the blackberry bore colorless fruit.

FIXING CHARACTERS

In a slightly different connection it may be noted that study of dominance and recessiveness in plant characters is of the utmost practical importance for the plant developer as an aid in fixing characters so that they will breed true, often a task of great difficulty.

This does not matter, of course, in the case of orchard fruits, which are propagated by grafting, and of various bulbous and other plants that are propagated by root division. But in case of annuals grown from the seed it is highly important that a new desirable character should be fixed in such a way that it will be reproduced in the progeny.

Now according to the Mendelian formula, in its simplest terms, where any pair of antagonistic characters that Mendelize are in question, the recessive character which disappears absolutely in the first filial generation will reappear tangibly in one in four of the offspring of the second generation, and will be submerged in the germ-plasm of two others of each group of four, the remaining member of the group being a pure dominant.

To illustrate from Mendel's careful experiments, when a tall and a short variety of garden pea are crossed, all the progeny are tall; but in the next generation one specimen in four is short and the other two specimens, while individually tall, have the factors for shortness submerged in their germ-plasm. The short specimen being purely recessive will breed true to shortness; but the two tall specimens that are mixed will not breed true.

The same principle holds for any pair of antagonistic characters that show the phenomena of dominance and recessiveness.

It follows that if a character which you are striving to fix in any given experiment is a recessive character, it is fixed from the moment when it reappears and you may give yourself no further concern in the matter. But if it be a dominant character, then you must be on the lookout, since of every three specimens that show the character, two will have factors for the antagonistic character in their germ-plasm, and do not constitute fixed strains. Only by watching through another generation can it be determined which individuals are "pure dominants," and such alone will breed true.

Until the Mendelian formula was known breeders were often put to their wits' end to segregate a strain that would breed true; whereas now, with the formula in mind, this may usually be accomplished in two generations.

LOOKING FORWARD

In the preceding pages a few of the general principles of plant development have been outlined, by way of a preliminary sketch of Mr. Burbank's methods. In the chapters that follow these methods will be illustrated at greater length and in much fuller detail. It seemed well, however, to prepare the reader with this preliminary outline for the detailed studies that are to follow.

In the immediately succeeding chapters, we

A FIELD OF SPINELESS CACTUS AT SANTA ROSA

The spineless cactus furnishes one of the chief exhibits in Mr. Burbank's garden at Santa Rosa at present. The picture suggests the prolific growth of this most productive of all forage plants.

I

K IN ORCHARD,
ⱽD FOREST

shall take up the practical aspects of Mr. Burbank's work, in effect going with him into the fields and observing the carrying out of the practical work of the horticulturist. It will be convenient first to examine his method of caring for seeds and the nature and development of seedlings. Then in successive chapters we shall go with him into the orchard, the small-fruit garden, the vegetable and flower gardens, and the lawn and dooryard, gaining characteristic glimpses of his manifold activities.

It is obvious that with the space at command it would be impossible to name each and every one of the plants with which Mr. Burbank has experimented effectively. At best we can mention only the more typical or the more spectacular cases. But I would again remind the reader that a very complete exposition of his entire lifework has been given by Mr. Burbank himself in a series of volumes, twelve in number, illustrated by no fewer that twelve hundred and sixty beautiful color plates. To this work the reader who wishes a more extensive presentation of the work of plant development as carried out by the Santa Rosa experimenter may turn with full confidence and with pleasurable anticipations.

Meantime it may not be amiss to repeat that the present book, although necessarily condensed in its treatment, endeavors to give the essentials of Mr. Burbank's methods and results, and that the illustrations of Mr. Burbank's work here presented are drawn from a first-hand study of his activities at Santa Rosa and Sebastopol, and the fullest examination of the original manuscripts and records made accessible to the writer in his capacity of editor-in-chief of Mr. Burbank's works.

PART II

WITH LUTHER BURBANK IN ORCHARD, GARDEN, FIELD, AND FOREST

CHAPTER III

THE CARE OF SEEDS AND SEEDLINGS

IT will give new zest to your work in the garden to feel that you are producing new varieties of vegetables or fruit or flowers not only different from those of your neighbors, but different from anything that ever existed before. It would have seemed paradoxical a few years ago to suggest such creative possibilities, but Mr. Burbank has shown the way, and the succeeding chapters will relate his methods clearly and explicitly.

In broad general terms, it may be said that the Burbank method consists of (1) the selection of desired traits and their accentuation through successive generations, combined with (2) artificial hybridization through which variation is stimulated, and through which different racial strains are brought together to produce unique combinations.

The precise way in which such selective breeding is carried out will be specifically detailed in connection with our studies of work in the orchard, the small-fruit garden, the vegetable garden, the flower garden, and on the lawn.

But as preliminary to such studies, it will be well to learn just how Mr. Burbank prepares the soil and carries out the tedious but necessary steps of seed planting and the nurture of seedlings, which are substantially the same for all types of vegetables, and which are among the most essential of the processes of practical gardening.

CHOICE AND CARE OF SEEDS

It is obvious that no success could attend the effort at plant development unless seeds are properly chosen and properly cared for. After experiments are under way, you will of course gather seeds from your own plants, but at the beginning of your experiments you must secure seeds from some other source. Mr. Burbank especially cautions you to procure your supplies from some reputable seedsman, so that you may have fair assurance that you are making a good beginning. It is obviously foolish to begin with poor varieties, when you might with equal ease have good varieties from which to select. Study seed catalogues, then, and decide on a certain number of species with which you wish to experiment, and secure seeds of the best available varieties of the species.

Mr. Burbank himself regards the care of seeds as among the very most important phases of his work. The seeds of his choicest varieties are kept over winter in boxes in a room of his own dwelling, where they are directly under his eye, and the method of dealing with these seeds in the early springtime is one to which he has given a vast deal of attention, and regarding which he has perfected a plan that insures the best possible results.

Fortunately, the method of sprouting seeds is practically the same for the most diverse kinds. Mr. Burbank has seeds sent him from all parts of the world. He applies the same method of germination to them all, and he has so perfected the method that he confidently expects to secure at least ninety-nine seedlings from every hundred seeds of whatever kind.

The importance of being able to germinate seeds of rare exotics with some such degree of certainty is obvious. It is no less important to make sure of the germination of seeds produced by difficult hybridizing experiments. For example, Mr. Burbank worked for twenty-five years unsuccessfully in attempting to hybridize two species of nightshade, and finally he produced a single berry. The solicitude with which he guarded the seeds of that berry may well be imagined. From one of those seeds sprang the plant that became the progenitor of the entire race of sunberries.

And this is only one instance of many in which all the potentialities of a new race of fruits or flowers or vegetables were represented in a little cluster of seeds that by the slightest mismanagement might be destroyed, thus bringing to naught a long series of experiments.

Bearing this in mind, we shall not wonder that Mr. Burbank keeps his unique collection of seeds constantly under his own eye, or that he personally supervises the planting of these seeds in the early springtime.

PREPARING THE SOIL

It is Mr. Burbank's unvarying custom to plant all important seeds in boxes that at first are kept in the greenhouse, so that the seedlings may get an early start, and for a time be protected from the elements.

For many years he has used boxes of a uniform size and type, and such boxes he considers far better than pots or earthen pans. The boxes he uses are eighteen inches square, outside measure, and four and one-half inches deep, inside measure. He prefers redwood lumber, but where this cannot be obtained cypress will answer nearly as well. Chestnut wood is also very durable, and locust is even more so. Soft pine should be avoided.

Two opposite sides of the box are boards three-quarters or seven-eighths of an inch thick, the other sides are a little less than half an inch thick. The bottom of the box is made of lumber about one-quarter of an inch thick, two or more spaces of an eighth of an inch being left for drainage. Across the bottoms are nailed three strips to add rigidity and strength, and to afford better ventilation and drainage.

It is well to dip the joints in linseed oil before they are nailed together. This gives durability and tends to prevent the nails from rusting.

Such a box as this, if sterilized once a year by being placed for three or four minutes in boiling water, may be used for many years.

In preparing the soil to fill the boxes, Mr. Bur-

SPINELESS CACTUS IN FRUIT

A glance at this picture will readily convince the reader that Mr. Burbank's spineless cactus, in its best fruiting varieties, is the most prolific of plants. The individual "cactus pears" are juicy fruits of palatable quality.

bank uses about one-half clean, rather coarse, sharp sand, and about forty per cent of good pasture or forest soil, preferably that containing more or less leaf mold. To this it is desirable to add from five to ten per cent finely powdered moss or peat. These ingredients are intimately mixed, with the addition of about one or two per cent of fine-ground bone meal or superphosphate, obtainable from any dealer in gardener's supplies.

This mixture makes a soil in which seeds of almost any kind of plant from any part of the world will germinate, and in which the seedlings will thrive until they are ready for transplanting.

Mr. Burbank recommends that soil of this kind, after being once used, shall not be thrown away, but shall be retained for mixture with new soil prepared in a succeeding season. He always keeps a little of the old soil on hand for this purpose.

If very choice seeds are to be grown, the soil, new or old, is sterilized by thorough scalding to destroy bacterial or fungus or insect pests.

Before filling the boxes with soil, it is well to scatter coarse gravel over the bottom to a depth of from one-quarter to a half inch. Use gravel that will just pass through a half-inch mesh, or a little smaller. This insures perfect drainage and sufficient aeration, both of which are of the utmost importance.

Then fill the box with the prepared soil to within about an inch of the top.

When cool damp weather is to be expected, and slow growth, make the filling somewhat shallower to prevent drowning or "damping off" of the seedlings. For spring planting make the earth a little deeper to prevent too sudden drying out, and otherwise to regulate the amount of moisture.

PLANTING THE SEEDS

Having filled the box with the prepared soil to the right depth, level the surface of the soil by pressing it down with a flat piece of board until it is smooth and fairly solid. Then sow the seeds quite thickly on this smooth surface, and dust a handful of the prepared soil over them. In the case of very small seeds, a mere sprinkling of the soil is enough. For larger seeds sprinkle the soil to a depth of one-eighth or one-quarter of an inch.

A very common mistake is to cover the seeds too deeply. It should be recalled that the tender sprout must force its way upward against the weight of soil that covers it. The soil covering should be sufficient to give it protection, but not enough to be burdensome. If too deeply covered, tender seedlings may not be able to force their way to the surface.

When seeds are planted in fields, and it is necessary to give them protection from the weather, Mr. Burbank entirely covers them with a thin layer of earth and sprinkles over this a layer of sawdust which will serve the purpose of equalizing the temperature, and will not subject the sprouting plant to undue weight. Even in the case of seeds planted in boxes the sawdust may be used, but in most cases powdered moss may be employed to better advantage.

A thin layer of moss sifted over the seeds acts as a non-conductive blanket, equalizing the temperature and retaining moisture.

A very thin layer of gravel or coarse sand may be sprinkled over the moss to hold it in place. This layer of gravel not only prevents the young plants from being washed about, but also serves as a barrier against the spread of fungous growths should they subsequently attack any of the seedlings.

After the seeds are planted and covered in the way just described, they should be watered not by sprinkling the surface, but by placing the boxes into a tub containing water of sufficient depth to rise nearly or quite to the surface of the soil. Thus in a few minutes the water saturates the entire contents of the box without disturbing the seed or packing the soil. The boxes are then removed and tilted to one side so that the superfluous water can drain out.

Mr. Burbank urges that every detail of this process of soil preparation and seed planting is of vital importance. By strict attention to details, success is virtually assured.

CARE OF THE SEEDLINGS

Of course the seed boxes should be kept at moderate temperature, in a fairly warm room, or in the greenhouse until the season is far enough advanced for outdoor transplanting.

If the season is delayed, it will be well to transplant the seedlings from the original box into another one similarly prepared, in order that they may have room to develop.

In the case of small plants like the calceolarias, lobelias, begonias, ferns, and the like, the little plantlets may be transplanted, as soon as they are visible, by lifting them on the end of a moistened quill, pencil, or small knife blade, and placing them in a box that has been previously moistened, then covering them with glass for a few days.

If the seedlings are not transplanted at this early stage, removal should not be deferred beyond the time when the little plants have from two to four leaves. Transplanting at this stage is a very simple process, effected with quill or knife blade. The seedlings should be placed in straight rows in new boxes, from six to twelve rows in a box, according to the size of the plants.

After remaining in the greenhouse for a week or two, the boxes of seedlings are removed to a sheltered place out of doors, in order that they may become hardened through exposure to sunshine and outdoor air. If the season is backward, it may be desirable to transplant the seedlings a second time into other boxes, to give them more room. But if the season is sufficiently advanced they may be transferred directly to the garden.

Mr. Burbank especially cautions against making too sudden a transfer from greenhouse to field. It is well to accustom the seedlings to out-of-door conditions by placing the boxes at first in propagating beds, surrounded by high boards, and covered with frames made of laths nailed on narrow strips of board in such a way that the spaces between the laths are about equal to the width of a single lath.

These frames give partial protection from sun and wind and prepare the seedlings for open-air conditions.

In making the final transplantation, it is well to take the boxes to the field so that each plant is transferred with the least possible exposure. In California tender plants best withstand moving from the greenhouse to the open air just before or during a warm rain, the atmospheric conditions at this time being similar to those of a greenhouse.

The final transplanting is done with a trowel, taking up enough dirt to include all the roots. Mark the rows with a guard line, and make a long narrow crevice by inserting a flat spade and moving the handle back and forth gently. Be sure that the crevice is deep enough to take in the roots of the plant fully extended. Plant the seedling a little deeper than it grew in the box, and draw the soil about it and pack it quite firmly against the roots. Use the common garden rake in leveling and loosening up the soil along each side of the row to prevent "baking," and to keep the temperature equable and the soil moist.

The tender seedlings may be destroyed by a cold dry wind, or by too much moisture and too little air. They should be protected for a day or two if a dry wind comes up, and the soil about them should not be soaked with water, although kept in a moist condition.

RUNNING THE GAUNTLET

There are numerous fungoid and insect pests that threaten the seedling during its infancy. Little patches of fungus may appear in a box of seedlings, and this may spread rapidly until the entire company is destroyed.

A sprinkling of sulphur over the plants, or of coarse dry sand or gravel about their roots, may prevent the fungus from spreading. It will be well to place the box in a cold dry atmosphere so that the excessive moisture is evaporated. The fungus pests are most likely to attack the seedlings if they have been kept in too close and damp an atmosphere.

After the plants are in the field they should quickly develop a hardiness that makes them immune to the attacks of fungoid pests. Mr. Burbank has all along made a very particular point of the development of hardy races of plants. He at once removes and destroys any seedlings that show susceptibility to the fungus or bacterial pests. In this way he develops races that are immune, and he never finds it necessary to use germicidal sprays in his orchards and gardens.

To a certain extent plants may be developed that are resistant also to the attacks of insect pests. But it is necessary to guard the tender seedlings against the attacks of these enemies. One should be on the lookout from the outset for the various cohorts of insects, slugs, cutworms, eel-worms, crickets, and aphides that feast on tender tissues of seedlings.

Slugs may sometimes be headed off by sprinkling lime, red pepper, quassia, or tobacco dust in their path.

The pests known as the thrips and the aphides are best destroyed by fumigating the greenhouse once or twice a month with tobacco smoke. In general a careful watch should be kept for the pests, and the seedlings mechanically guarded against them so far as possible. The proper sterilization of the soil at the outset will save a vast deal of trouble at a later stage.

The description just given outlines the method that Mr. Burbank applies to the seeds that come to him from all parts of the world and to those raised on his own grounds.

The rules just given for the planting of seeds and the early care of seedlings apply to plants of every description. Whatever the varieties with which you intend to experiment,—flowers, vegetables, small fruits, orchard fruits, or forest trees,—the initial steps are the same.

CHAPTER IV

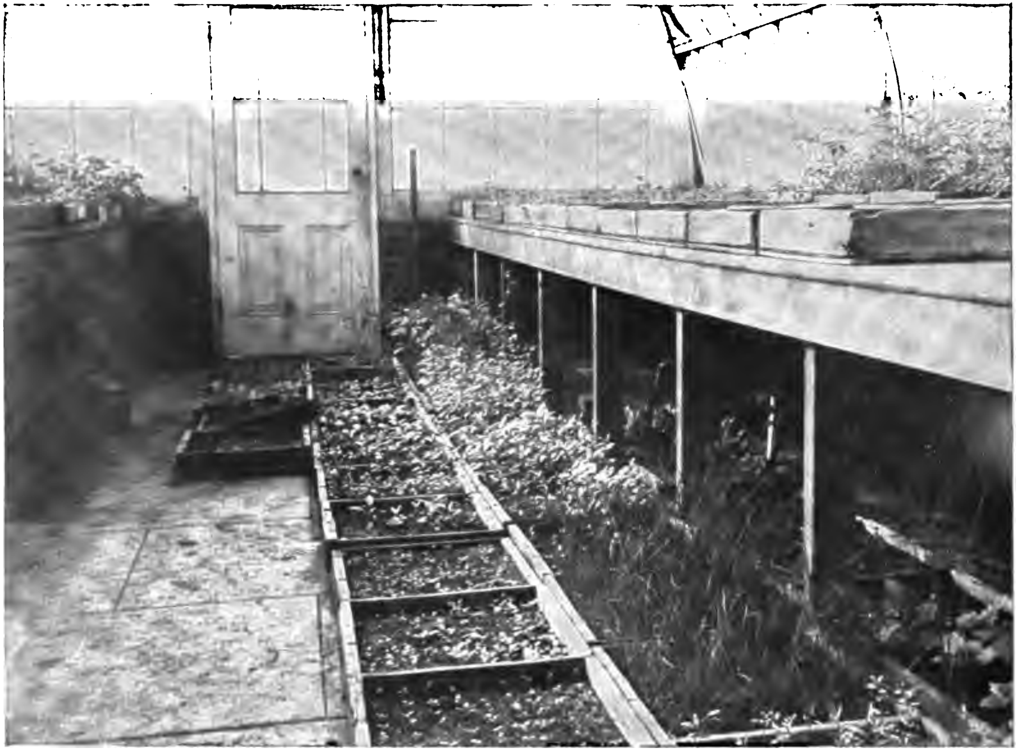
WITH BURBANK IN THE ORCHARD

ALMOST every country dooryard has one or two orchard trees in some odd corner,—an apple or pear tree, or cherry or plum. For the most part these trees bear indifferent fruit, and it does not occur to their owners that they could be improved. Yet in point of fact it would be an easy matter to graft scions or buds of good stock on these trees, and produce fruits of the finest varieties, instead of inferior ones.

You may have a hundred or more different varieties on a single tree if you like. Mr. Burbank sometimes has a thousand.

Moreover, it would be quite feasible to make the old tree the seat of experiments in the development of new kinds of fruit—absolutely new kinds, such as no one ever saw before. That is what Mr. Burbank would do with the tree. He would seek its co-operation at once; do some pollenizing and grafting; and pretty soon the old, "worthless" tree would be the most interesting and important tree in that part of the world.

The ensuing pages will tell just how he would go about it—and how you may imitate his methods.



BOXES OF SEEDLINGS IN MR. BURBANK'S CONSERVATORY

All manner of seeds are planted in boxes or "flats" of the type here shown. The seedlings are kept for a time in the conservatory, where they can be inspected from day to day, and ultimately transplanted or destroyed according to their merit or lack of it.

CREATING NEW SPECIES

Mr. Burbank early discovered that by hybridizing different species of plants he could produce new varieties—even new species.

At the time when this discovery was made most botanists and horticulturists supposed that a cross between two species would be infertile. Mr. Burbank proved that, quite to the contrary, some hybrids show an extraordinary degree of fecundity. Everything depends upon the degree of relationship of the parent forms. Species that are too widely separated do not interbreed. Those that are a little less widely separated may produce sterile offspring,—mules. Where the relationship is still closer, the hybrid offspring may not be sterile, and yet may be less productive than either parent.

But where the degree of affinity is just right, the offspring may show a vigor and fecundity far in excess of that of either parent.

The hybridizing of more or less closely related species and varieties of plants, then, constitutes a fundamental part of Mr. Burbank's procedure in the creation of new forms. He has hybridized about two hundred different species. Among the orchard fruits thus crossed are the plum and the apricot (producing the wonderful plumcot), apple and pear, apple and quince, quince and pear, peach and nectarine, peach and almond, and orange and lemon.

Strange and interesting forms have resulted from some of these crosses,—a smooth-skinned peach that bears an edible almond seed at its heart, to name a single example. Crosses between different varieties within a species have been made by thousands, producing hundreds of new varieties of plums, prunes, peaches, apples, pears, cherries, and quinces. Stoneless plums and prunes; plums that look like apples and taste like them; gigantic red-cheeked pears; cherries for canning that leave the stone on the tree when you pick them; colossal, savory quinces, borne on mere bushes—these are some of the results, named almost at random. Hybridizing experiments that hold out such possibilities are worth trying. We shall see how to go about them in a moment.

Another fundamental method, supplementing the method of hybridization, is that of selection among varying individuals of the same species or variety. No two individuals are just alike, from which it follows that in a given company of plants of the same kind there are various gradations as to size and shape of leaf, form and color of flower, or flavor of fruit; and, as regards each varying quality, there must obviously be one individual, if you will carefully search it out, that exhibits this quality most markedly. Or there may be an individual that shows just a trace of a new quality—say a unique flavor or color.

This is the individual to select for further breeding experiments, in expectation of accentuating the quality in question.

For instance, Mr. Burbank found a cherry that tended to fruit early: its descendant is the Early Burbank, which ripens three weeks before any other cherry. He found a hybrid prune that was a trifle sweeter than its fellows: its descendant is the Burbank sugar prune, with its twenty-three per cent sugar content. He found a quince with slightly modified texture and flavor: its descendant is the pineapple quince, gigantic in size, good to eat raw like an apple, and with the flavor of a pineapple. Any quality that can be detected at all can almost surely be accentuated by selective breeding.

SEEDS AND SEEDLINGS

In experimenting with a plant, Mr. Burbank has, of course, a clear idea of the modification he wishes to produce. As a rule, a number of qualities—often a dozen or more—are under consideration at the same time.

If the fruit is a cherry, for example, it will perhaps be desirable to enlarge the fruit, make it sweeter, redder, and juicier; improve its keeping quality; decrease the size of the stone, and shorten the stem; while at the same time making the tree a hardy, regular, and prolific bearer, with the fixed habit of ripening its fruit very early in the season.

To get such a combination, the right heredities must be blended, as a matter of course. But there will be extraordinary diversities in the same fraternity; and the chance of securing a plant that shows any given combination of qualities in superlative degree increases in direct proportion with the number of seedlings from which selection can be made.

Hence one of Mr. Burbank's hobbies is the production of seedlings in great quantity. This is not so essential in hybrid seedlings in the first generation, but it is highly important in the second generation, because then the plants begin to show a very wide range of variation—for reasons that we shall examine in another connection.

So Mr. Burbank saves all the seeds of a plant that attracts his attention, and sows them in a carefully prepared soil in greenhouse boxes. Details as to his method have already been given. We may add that the same method is used for seeds of practically every variety,—rare exotics of many kinds and the commonest garden plant; seed of the spineless cactus or that of orchard fruit. Whatever the variety, Mr. Burbank nurtures and transplants the tiny seedlings, giving each one of them a chance to show its quality in open competition.

RUNNING THE GAUNTLET

The tiny seedlings of the plum or the cherry or apple or pear or quince are transplanted into a field pretty close together, for economy of space, and are carefully weeded and cultivated until they attain an average growth of about one foot.

Then Mr. Burbank subjects them to a rigid inspection. He passes along the row, and gives a quick but searching glance at each successive seedling. He knows precisely what he is looking for, and his eye detects niceties of variation that would be discerned by no one else.

Mr. Burbank is able thus to pass under review, for appraisal, five thousand, ten thousand, even twenty thousand seedlings in an hour. This capacity for almost occult divination of the qualities of the seedling enables him to make thousands of series of experiments simultaneously, and to test millions of plants on experiment farms that have an aggregate surface of only twenty-two acres. He is always carrying forward at least three thousand series of experiments. All in all, he has carried out more than one hundred thousand such series of experiments, involving almost as many varieties of plants (for he seldom repeats an experiment), and more than three thousand distinct species.

It will be understood, of course, that the experiment is not finished when the seedlings are selected. It is really only begun. The selected seedling must be grafted, and allowed in due course to bear fruit. Then, and not before, can its quality be finally and positively known.

Visitors who have seen Mr. Burbank making such a test as that just suggested have sometimes questioned whether it could possibly be a really accurate one.

The results achieved should fairly enough answer the question, but the matter has been put to an even more decisive test. On one occasion, Mr. Burbank was selecting among thousands of plum seedlings, directing his assistants to uproot them and deposit them in three piles,—a very small pile for those that he deemed excellent, a medium-sized pile for the fairly good ones, and a large pile for those that were regarded as worthless.

An amateur horticulturist who watched him declared that he was making the selection much too rapidly, and that he could not possibly forecast the possibilities of the seedling with certainty. Mr. Burbank suggested that he put the matter to a test.

Accordingly a bunch of seedlings was taken from each pile, and grafted on three plum trees of similar size and character that stood side by side.

Of course it was necessary to wait two or three years to learn the result. But when the grafted scions were old enough to bear fruit, the accuracy of Mr. Burbank's prevision was fully proved. The scions from the rejected lot bore no fruit of value. Those from the medium lot bore some fairly good fruit, but not one that produced a variety of exceptional value.

Meantime the tree bearing the scions that were originally selected as "best" bore such a profusion of excellent fruit, of twenty-three different new varieties, that the amateur who had suggested the experiment named it the Klondike, declaring that he had never before seen so much good fruit on a single tree.

HOW TO SELECT SEEDLINGS

This capacity to judge the possibilities of a future tree by merely glancing at the seedling is doubtless in part a matter of intuition.

It has been said of Mr. Burbank, perhaps without much exaggeration, that he has the keenest senses of any man in the world. But of course a profound knowledge, based on a lifetime of study, supplements and checks direct observation, and something of this knowledge can be conveyed to others.

Doubtless no one else can hope to select seedlings with quite the certainty of the master, yet everyone can learn at least a few general characteristics that should be looked for in the seedling of a future fruit tree.

Mr. Burbank tells us that the desirable qualities include relative thickness and sturdiness of stock and branches, round "fat" buds, and large thick leaves of deep rich color. Vigor of growth is also important, this being an inherent trait that is manifested by the seedling from the moment that it breaks through the soil. A tendency to upright growth is also desirable. A seedling that shows these qualities, and that has the general appearance of health and entire freedom from fungous growths, may safely be looked to as a future producer of fruit of good quality.

On the other hand, a seedling that lacks vigor, is of slender stock and branch, with thin buds and leaves of poor shape or faded color, should be rejected. And in particular, any seedling that is attacked by mildew or other fungous growths, whatever its other qualities, should be at once uprooted. Immunity to disease is a *sine qua non*. The quality that gives immunity is inherent in the germ-plasm of the individual, and a susceptible seedling will make a susceptible tree.

Mr. Burbank's trees do not need to be sprayed to protect them against bacterial and fungous diseases, because they are raised from immune stock.

In developing an orchard you will do well to follow the same rule rigidly, even though it leads you to destroy seedlings that otherwise appeared to be the best in an entire lot.

HURRYING THE SEEDLINGS BY GRAFTING

Of course the seedlings that are selected for preservation might be transplanted and left to develop on their own roots.

But this would be much too slow a process to meet the needs of Mr. Burbank's experiments. He knows that as a rule he must carry the experiment through several generations before he has developed the choice new variety of fruit that he has in mind.

That is to say, he must await the flowering of his seedlings; cross-fertilize them; save the seeds of their fruit, plant them, and raise another crop of seedlings; which in turn will be submitted to the same process of selection, grafting, and cross-fertilization. The object is to breed into the com-

MR. BURBANK INSPECTING CROSS-BRED TOMATO SEEDLINGS

The specimens depicted were altogether extraordinary, in that the cotyledons shown when they first issued from the ground were not smooth, as is almost invariable with every species of plants, but deeply serrated. In all Mr. Burbank's experiments, involving inspection of millions on millions of seedlings, he has never observed this phenomenon before. These specimens appeared in the season of 1914.

plex hybrid the diverse traits of different species. Of course only two species can be blended in a single cross, so repeated crossings will be necessary.

Obviously, then, it is desirable to shorten as much as possible the interval between generations. And Mr. Burbank has learned that the way in which this may best be accomplished is by cutting the seedling from its own roots, and grafting it as a scion on the branch of a mature tree.

He has discovered that if the graft is placed on the trunk of a tree or on a large branch, it will develop less rapidly than if placed on a twig near the end of a branch. So he grafts his seedlings in this way when they are very small, putting them on branches that are usually not more than half an inch in diameter. Thus placed, the scions usually bear fruit in the second year (exceptionally, even in the first), whereas if they had been left to grow on their own roots they might not have borne until the fifth or sixth year.

Thus an experiment may be carried through four or five generations in the time that would otherwise be required for two generations. By the adoption of such time-saving methods, Mr. Burbank has been able to crowd the work of several human generations into a single lifetime.

There are several methods of grafting, but the essential principle with all of them is merely that the inner or living layer of the bark—called the cambium layer—of the stock and scion shall be brought in contact, not necessarily throughout its extent, but at least in one place. If a scion is to be grafted on a branch of its own size, or not very much larger, each is cut across obliquely, and each is slit or notched, so that when pressed together they interlock, the scion thus being held pretty firmly. Such a graft is called a "whip" graft or "splice" graft.

A scion may be engrafted on the trunk of a sapling by bending the sapling and making an oblique incision with a knife, into which the wedge-shaped scion is inserted, care being taken, of course, that the living tissues come in contact. This is called a "side" graft. The same method may be employed to graft a scion on the root of a tree.

Where the graft is planted on a larger limb, the method of "cleft" grafting is employed. This consists of sawing off the branch of the stock, and splitting it with a knife or wedge at the end. The base of the scion is cut into a wedge shape, and this is thrust into the cleft in such a way that the inner bark of the scion comes in contact with that of the stock. A scion may be inserted on either side of the stock, or in the case of a large branch four or more scions may be placed on the same branch.

The process of grafting is completed by covering the exposed surfaces with grafting-wax, and wrapping a cloth about the branch for further protection during the time of healing. Mr. Burbank's formula for grafting-wax is as follows:

"Eight pounds of resin and one pound of beeswax or paraffin (either will do if no acid or alkali is present, though beeswax is generally preferred) are mixed with one and one-half pounds of raw linseed oil. Boiled oil should be avoided, as it often contains chemicals injurious to plant life. If the wax is to be used in cold weather, it is better to use only seven and one-half pounds of resin and a half-pound of beeswax in the mixture, thus giving a slightly thinner consistency."

The ingredients are slowly heated together until melted and thoroughly combined. When partly cool, the composition is poured into pressed tin pans, from which the cakes may be removed when needed by turning the pan upside down and pouring boiling water over it for a few seconds. For use, the wax is heated, preferably in a double heater, the outer one containing water, to prevent overheating. It is applied with a small paint-brush, first around the thick bark of the stock, and later, as the wax on the brush cools, on and about the cut surfaces and open joints.

THE PROCESS OF BUDDING

When Mr. Burbank has to deal with a very rare seedling, or one that he wishes to multiply rapidly, he uses the modified form of grafting known as budding.

The process consists in slicing off a well-ripened bud, including a piece of bark about an inch and a half long, the incision being just deep enough to include the cambium layer and a small portion of wood. A T-shaped incision is made in the bark of the tree that is to serve as host; the upper corners of the vertical slit are gently lifted with a knife and turned back to reveal the cambium layer; and the bud is slipped into the little pocket thus formed, and the flaps of bark are brought over it and securely tied. No wax is required. The binding cord must be removed in from ten to fourteen days, in order not to constrict the branch.

Ordinary grafting, as described above, may best be performed rather early in the spring, or just as the buds are starting. But budding is usually done in June, July, or August, while the trees are in full leaf and vigorous growth. Perhaps the best time is just before the end of the most rapid-growing season in the early summer. If transplanted late in summer, the bud usually remains dormant until the following spring.

If budding is done in June, the branch should be broken over a short distance above the bud, but not at first wholly removed, to keep up a partial circulation. The bud may then start growing almost immediately. These are called June buds by nurserymen.

A branch from three to six feet in length may grow from a bud in a single season.

If you have young seedlings with vigorous roots, they may be grafted or budded with choice varieties, and in many cases a better tree will be secured than if it grew on its own roots. It will be understood, however, that scions must be grafted on trees of kindred species. You cannot graft a stone fruit, for example, on a seed fruit, or vice versa. But a cultivated apple may thrive when grafted on roots of the wild crab apple. Pear scions do well on wild or inferior varieties of pears. Cultivated varieties of plums may be grafted on hardy and vigorous wild plums. Apricot scions thrive on seedling plum or peach stock.

One of Mr. Burbank's striking feats in his early experience in California, while he was carrying on the business of a nurseryman, was to establish an orchard of twenty thousand prunes in a single season by raising almonds from seed (sprouting them between layers of gunnysack covered with moist sand), and grafting prune scions on them as soon as they were large enough.

Mr. Burbank habitually tests scores or even hundreds of new varieties on a single tree. On his Gold Ridge Farm at Sebastopol there are single acres on which ripen several thousand distinct varieties of hybrid seedling plums that, if tested each on a separate tree, would require, it is estimated, something like seven hundred acres of land.

It is obvious, then, that if you have on your grounds an apple tree or two, a plum, a pear, and a cherry, even if they are all of inferior varieties, you may quickly establish colonies of all the common orchard fruits, in the choicest varieties, by grafting or budding with scions that may be secured from any good nursery.

Under the circumstances, it is your own fault if your trees do not produce good fruit.

SEEKING NEW VARIETIES

An added advantage that Mr. Burbank gains by having many varieties of an orchard fruit growing on a single tree is that the process of hybridizing, through which, as we have seen, new varieties are developed, is thus facilitated. This process consists primarily in fertilizing the flower of one variety with pollen from another. The process is a simple one, particularly in the case of the orchard fruits. Its results are sometimes very remarkable, but of course they are not immediately manifest.

If you examine the flower of apple or plum or cherry, you will see that it bears a cluster of stamens grouped about the central pistil. Each stamen has at its end an anther that when mature bursts open and reveals a quantity of pollen.

Under natural conditions the pollen is transferred from one flower to another through the agency of bees, and natural hybrids are not infrequently thus produced.

All that is necessary to produce cross-fertilization (where the plants are closely related) is to transfer pollen from one flower to the pistil of another. It will be well to remove the stamens from the flower to be fertilized, with a pair of small forceps, before they have ripened, thus preventing self-fertilization. Then the pollen from another flower may be dusted on a watch crystal, and thence transferred with the finger tip or with a small camel's-hair brush to the pistil of the flower to be fertilized.

Cover the pistil thoroughly with pollen, and there will be little danger that any foreign pollen may subsequently find lodgment; particularly if the petals of the flower are cut away, so that it will no longer attract bees.

Mr. Burbank sometimes saves time, in the case of orchard fruits, by operating on a blossom just before it opens, cutting it across with a sharp knife in such a way as to remove the pollen-bearing anthers at the ends of the stamens, care being taken not to injure the pistil at the center of the flower. Pollenation is then effected (after the pistil ripens) in the way just described.

In operating on a large scale, Mr. Burbank does not find it expedient to cover the flowers with paper bags, nor does he think it necessary to do so. But the amateur who has plenty of time at his disposal may give the flowers this added protection if he so desires. The object is simply to make sure that the bees do not accidentally transfer pollen to the pistil, and thus perhaps complicate the experiment.

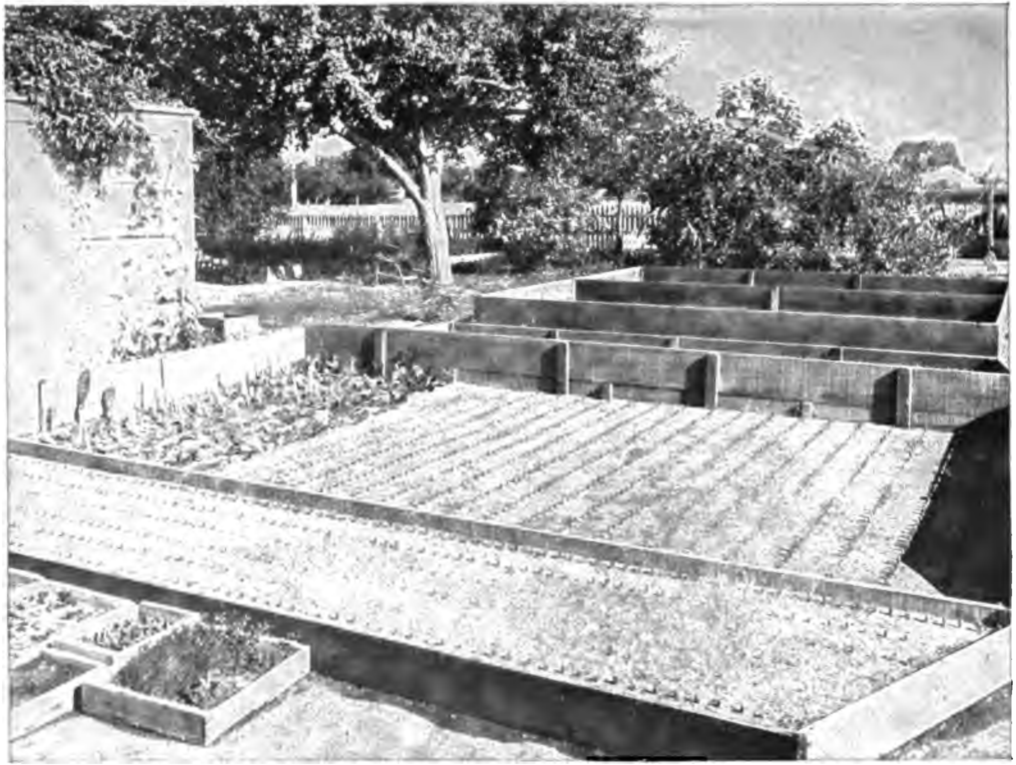
Such cross-pollenation, through which the strains of various races or species of orchard fruits are blended, constitutes a very essential part of Mr. Burbank's work. In this way he has brought together the racial strains of plums from

Japan and Europe, and blended them with those of American plums, producing extraordinary new varieties; and the strains of apples, pears, peaches, quinces, and cherries, from the most widely separated geographical regions, have been similarly blended.

CREATING NEW FRUITS

One time when Mr. Burbank was a young man he was browsing in a San Francisco library, and came across an account, written by a wandering sailor, of a remarkable red plum found in Japan, and spoken of by the sailor as the "Blood Plum of Satsuma." Mr. Burbank at once sent to Japan for this plum, among others, and he ultimately secured a specimen, which became the progenitor of all the different varieties of red-fleshed plums that are now to be found anywhere in America. Some of the other Japanese plums,—and the Chinese plum as well,—when blended with American and European plums, were equally notable as producers of new and remarkable varieties.

Of the sixty odd new varieties of plums and prunes that Mr. Burbank has introduced, no fewer than thirty-eight bear strains of the Asiatic plums, fourteen were developed from American stock, and thirteen from European species. But the various strains have been intimately blended. A single complex hybrid may reveal the brilliant color and delicious fragrance of the Chinese plum, the red fruit pulp and large size of the Japanese,



THE CULTURE OF SEEDLINGS AT SANTA ROSA

A corner of Mr. Burbank's garden showing beds of seedling cactus plants, being tested for the spineless quality. Note the neat, trim appearance of the beds, which is thoroughly characteristic of all Mr. Burbank's work.

the hardiness and fine flavor of an American wild plum, and the sweeetness of a European progenitor.

By hundreds of carloads, in the aggregate, the various Burbank hybrid plums are sent to the eastern markets each season.

One of Mr. Burbank's most celebrated experiments was that in which he hybridized the plum and the apricot, producing a wonderful new fruit, the plumcot. The hybridization was effected with difficulty, because the two strains were so distantly related, but it was finally accomplished, and now there are many varieties of plumcots in the orchards at Sebastopol.

Among the new varieties that Mr. Burbank has developed by this method, none perhaps has excited more general interest than the stoneless plum. A fruit that exteriorly looks like any other plum, yet which offers no resistance to the teeth when you bite right through it, is obviously something quite out of the ordinary.

The stoneless plum was developed by a long series of hybridizing experiments in which the original progenitor was a small "freak" plum of acrid and inedible quality, that through some abnormality was partially stoneless. This little plum grew wild in France, and was not considered of any value. Mr. Burbank secured a specimen, however, and hybridized its blossoms with various cultivated plums.

The problem was, to breed into the hybrid the qualities of the commercial plum, while retaining and accentuating the tendency to stonelessness. This proved exceedingly difficult. But by persevering through a long series of generations, saving always for seed purposes the seedlings that showed most improvement, and grafting them in the way above described to hasten their development, Mr. Burbank finally succeeded in producing not merely one variety, but several varieties of plums and prunes of large size and of excellent quality that are almost absolutely stoneless, retaining at most a tiny fragment of shell at one end of the seed. Some varieties have shown a marked tendency to eliminate the seed itself as well.

The contrast between the cranberry-sized partially stoneless French plum, with its inedible flesh, and the mammoth stoneless plum of delicious quality that is descended from it is very striking.

SUGGESTIONS FOR THE AMATEUR

The development of such a fruit required years of time and an almost inexhaustible supply of energy and patience. But the principles involved, from first to last, were merely those that have been outlined above. Hybridization and selection —these are the methods of the fruit developer as perfected by Mr. Burbank. Intelligently interpreted and systematically followed up, they make possible almost any desired transformation in plant life.

Let this not be misunderstood. Selection of material and the right blending of the material are the essential methods of the plant developer. But the creative work of a master painter might be described in the same terms. In each case, everything depends upon *how* the materials are used.

The "wizardry" that one hears ascribed—and very justly ascribed—to Mr. Burbank has for accessories the methods of hybridization and selection, but these are applied with (1) the creative genius that can conceive the ideal of a specific plant development, plus (2) prevision in selecting forms to hybridize, plus (3) a sixth-sense intuition in noting nice shades of variation, plus (4) indefatigable energy in following up an experiment, and inexhaustible patience in the face of temporary bafflement.

In a word, certain mechanical methods *plus genius* account for the work of Luther Burbank. But the mechanical methods, after all, are essentials. You cannot become a master painter merely by inspecting the palette of a great artist; but you can never hope to paint at all if you do not learn the rudiments of pigment-mixing. Similarly you will not necessarily become a Burbank because you learn to hybridize and select, but you must learn these things if you are to attempt plant development at all.

Moreover, here, as in many other fields, you may repeat an experiment that you might not have preconceived. Many an amateur can make a fairly presentable copy of a masterpiece.

Each of Mr. Burbank's great plant developments is a masterpiece of experimental application. Yet many of these developments might be duplicated, now that the methods are known, by any intelligent amateur who will give attention to details.

It is possible for you to apply the methods on a small scale even though you have but a single fruit tree. Indeed, with a ten-foot plot of ground for the raising of seedlings, and a single tree on which to graft, you may experiment to your heart's content.

And although you cannot expect to produce plumcots or stoneless plums or superlative varieties of peaches or apples or pears or cherries without expenditure of effort, you may at least hope to develop interesting modifications in the fruits with which you operate, even though you devote only an occasional half-hour to the experiment.

You may secure any amount of material for the development of new varieties merely by planting the first seeds of apple or pear or plum that come to hand. For the cultivated varieties of orchard fruits do not breed true from seeds. You will not secure Baldwin apples, for example, with any certainty, by planting the seeds of the Baldwin. But this is an advantage from the standpoint of the plant experimenter. You may make sure of interesting developments by planting the seeds of any orchard fruit that you secure in the market, and working with the seedlings along the lines suggested above.

Mr. Burbank has used the wild crab apple in some of his experiments, and has produced a hybrid of large size, retaining certain qualities of the wild fruit. He has also developed an extraordinary plum, of enormous size and of almost incredible productivity, by hybridizing the little beach plum with various cultivated varieties.

These are experiments that you may duplicate with very little trouble, the results of which are sure to be surprising and fascinating.

Even before the blossoms come, you may begin operations by grafting scions of good varieties on the branches of your old trees. Also, you should start at once germinating some seeds, to raise seedlings that will be grafted or budded on your trees later in the season.

If, in addition, you will prune your old orchard trees thoroughly, and cultivate and fertilize the soil about their roots, you will have prepared the way for a crop of improved fruit the coming fall, and for a series of fascinating experiments in the development of new varieties.

You may plant the seeds at once on taking them from the fruit, as soon as the fruit is ripe in the fall, provided you have a warm place in which to keep them over winter. Plant them in a box or can, in soil prepared according to Mr. Burbank's formula already given. They will thus get a good start, and will be ready for transplanting or for grafting in the early spring.

If, on the other hand, you keep the seeds over winter, they should be kept slightly moist, as they will not germinate readily, if at all, if they are allowed to become thoroughly dry. They may be kept in sand that is slightly moistened (not wet) in a cool place. The seedlings grown from seeds planted in the early spring will be ready to supply material for summer budding, or they may be left on their own roots throughout the season, to be grafted early in the succeeding spring.

Meantime you may extend the scope of your operations, and prepare for a wider range of experiment next season, by hybridizing the flowers of any orchard trees that chance to grow in your dooryard. You may secure a few apple blossoms from your neighbor's orchard, and by pollenating the blossoms on your own tree prepare the way for interesting developments. Also, if trees are at hand, try pollenizing apple and pear, or pear and quince, or wild crab and cultivated apple, or wild plum and domestic plum, or wild cherry and cultivated cherry.

There will be no obvious immediate effect on the flower that you thus cross-fertilize. The fruit that develops will be the same in appearance that it would have been if fertilization had been effected in the ordinary way with pollen of its own kind. But the seeds are profoundly affected in their germinal matter. You must extract the seeds when the fruit is ripe, and either plant them at once or keep them over winter as above suggested. The seedlings that grow from them will be hybrids combining the qualities of the two parent forms. Just what the result will be cannot be known until the seedlings are old enough to bear fruit,—which, if they are properly grafted, will be in their second or third year. Then surprises will be in store for you. Not even Mr. Burbank himself could predict what the new fruit may be like in a given case. But it is certain to be something different from either parent—a new form of plant life that you have brought into being by combining different racial strains.

CHAPTER V

NEW BERRIES AND GARDEN FRUITS

FEW aspects of Mr. Burbank's work have been more spectacular than those having to do with the production of new berries. He has hybridized the blackberry and the raspberry, producing new types of berry that are entitled to rank as new species. He has also hybridized the strawberry and the raspberry, and has crossed the dewberry with such divergent forms as the apple, the pear, the mountain ash, and the rose. The last-named crosses produced remarkable plants, but these did not bear fertile fruit.

It is quite within the possibilities, however, that some other worker may repeat these experiments, and produce berries as new and wonderful as the Primus berry, the Phenomenal berry, the Paradox berry, or the white blackberry, these being four of Mr. Burbank's most wonderful creations.

The way in which these berries were developed is here told in detail; also the story of the thornless blackberry, the sunberry, and the improved cactus pear. The practical directions given will enable the amateur to improve any varieties of berries in his garden by selective breeding, and to produce new varieties that are different from

A CLEFT GRAFT.

This reproduction of a color-photograph illustrates one of several common methods of grafting, as practiced in Mr. Burbank's orchard. The engrafted twigs are called "Scions," the branch on which they are placed is called the "Stock." The essential principle is that the inner bark, called the Cambium layer, of the scion, should be brought into intimate contact with the corresponding layer of bark of the stock. The work is completed by covering stock and scion with grafting wax, and wrapping cloth about the stock for further protection.

any ever seen before, and superior to anything now in your garden, whether or not they rival the extraordinary ones that Mr. Burbank has created.

CULTURE OF GARDEN FRUITS

The small fruits make a special appeal to the amateur, because they are so easily grown and do not demand so much patience in awaiting results as do the orchard fruits.

Any odd corner of your garden will afford opportunity for a berry patch. Almost any soil will do, but that which is loose and loamy or sandy is best.

It is Mr. Burbank's custom to plant the seeds of raspberries and blackberries as soon as the fruit ripens. He merely crushes the fruit gently, washes away the pulp, and plants the seeds in boxes which are transferred to the greenhouse in the winter. They will thus make an early start in the spring, and you will gain several months' time. If you have not a greenhouse available, it will be necessary to wait till the following spring before planting; but the seeds are not injured by drying.

If the seeds are planted in boxes, transplant them when two or three inches high into rows about three and one-half feet apart, the individual plants being placed about a foot apart. Let the seedlings run wild until they come to fruiting age. Then rigidly destroy the plants that produce inferior fruit.

The plants selected for preservation may be trained on posts or trellises, and made to take any desired shape by nipping off the tips of stalk or branches. The old wood should be cut away from time to time. The best plants may be propagated by tips or by suckers.

REMARKABLE HYBRIDS

The blackberry and raspberry represent two obviously related and familiar types of fruit, each of which has characteristic qualities. But there are many species of each group, and these may be interbred indiscriminately, offering the most inviting opportunities for the creation of new varieties.

When Mr. Burbank fertilized the dewberry with pollen from the apple, the pear, the mountain ash, and the rose, he was carrying hybridization to something like its limits. The plants belong to the same family, but the dewberry is not of the same genus with any of the others.

The fruit that formed was not visibly different from other dewberries. But strange potentialities were blended in the seeds.

The plants that grew from those seeds next season showed the most extraordinary range and variation of vine and leaf and flower. A few of them formed berries, but in all cases these berries were without seeds, or the seeds lacked the germinating kernel. In other words, the strange hybrids were infertile. It would appear that the hereditary strains thus brought together were too widely divergent for compromise.

A somewhat similar result was obtained when Mr. Burbank brought pollen from a strawberry flower and placed it on the pistil of the flower of a raspberry. The seeds of the raspberry were carefully preserved, and next season they germinated and produced plants which at first had all the appearance of the strawberry plant, but which subsequently sent up stalks not unlike those of the raspberry. The leaves of the curious hybrid, however, were always trifoliate, like the leaves of the strawberry.

The plants blossomed, but formed only abortive berries that had no seeds.

On the other hand, when Mr. Burbank fertilized the flower of the dewberry with pollen of a raspberry plant he had imported from Siberia, one of the numerous hybrid offspring showed great vigor, having a much larger leaf than either of its parents, and producing a fruit that also was much larger than that of either parent. This fruit was named the Primus berry. It has the outward appearance of a blackberry, but if allowed to remain on the vines until entirely ripe, it parts from the receptacle on being picked, just as a raspberry does.

The Primus berry is a hybrid of the first generation, which appears to blend the qualities of its parents in about equal proportions. Curiously enough it did not revert to the form of either parent in the next generation, though thousands of seedlings have since been grown from it. On the contrary, it breeds true from the seeds—as true as any wild species, and far more true than most cultivated ones. Thus it gives every evidence of constituting a fixed species, sprung into being in a single generation.

This is believed to be the very first new species of plant ever produced under conscious human direction. Its production marked an epoch in the history of plant development,—not because of the qualities of the Primus berry itself, which is of a flavor not generally appreciated, but because of the demonstration that a new species could be produced by hybridization. Instead of being infertile as hybrids were supposed to be, the new berry proved enormously productive.

Another variation in application of the laws of heredity was illustrated when Mr. Burbank crossed the California dewberry and the Cuthbert raspberry. Here the hybrid progeny were of various forms, but they were all red in color, though the seed parent was the blackberry. The hybrids proved fertile, and a few of the best of them were preserved and inbred through successive generations. In the second generation one of these produced a berry of extraordinary size—perhaps the largest berry ever seen—which resembles a blackberry in general appearance but is bright clear red in color, showing the influence of the raspberry grandparent. This berry was named the Phenomenal. It has a fine flavor and has gained great popularity.

This fruit is so different from either raspberry or blackberry that the nurserymen classify it with neither, but in a new group. The combination is so fixed that there is never reversion to either raspberry or blackberry in any generation. In other words, the Phenomenal berry also is a new species that breeds true.

The Paradox berry has for its ancestors the Lawton blackberry and the Crystal White blackberry. The hybrid offspring of this union were selected and inbred through several generations, and the berry named the Paradox appeared in the fourth generation.

Of these three remarkable new species of brier fruits, then, one is a first-generation hybrid, another a second-generation hybrid, and the third a fourth-generation hybrid.

QUANTITY PRODUCTION

It must be understood that in each case Mr. Burbank was dealing with large numbers of hybrids, and that the berry finally selected and named was the best individual in a fraternity that included thousands or tens of thousands of individuals. While the blackberry-raspberry experiments were under way, indeed, Mr. Burbank had occasion each successive season to select a few individuals as representing most nearly the ideal at which he aimed, the remaining plants being uprooted, piled in a heap, and burned.

On one occasion no fewer than 65,000 hybrid plants of the blackberry and raspberry were thus consumed.

Many of these vines bore excellent fruit, but it was impractical to sell them or give them away, because some of the recipients would have been sure sooner or later to announce their fruits as "Luther Burbank's finest creation," to the disadvantage of the purchaser and to the detriment of Mr. Burbank's reputation. The plant developer himself never puts a new variety on the market unless he believes it to be superior to any existing variety in at last one respect, and equal to any other in all respects. His reputation has been made by following this rule, and he cannot afford to jeopardize it by allowing any new variety that does not conform to this test to be put on the market.

Hence the necessity for the not infrequent "ten-thousand-dollar bonfires" through which the discarded plants that have entered into his experiments are destroyed.

When we learn that the original Paradox berry vine was the only individual saved among forty thousand hybrids, our first thought is likely to be that it is an almost hopeless task for the amateur to attempt to develop a new variety of small fruit.

But it should be explained that the standard of the amateur need not be so high as the standard that Mr. Burbank establishes. Among the forty thousand discarded vines there were doubtless large numbers producing new varieties of berries that would have been highly satisfactory to almost any other experimenter.

Mr. Burbank was looking for the *one best* berry, and he took no interest in a second-best.

The amateur who is experimenting for his own pleasure rather than for the production of commercial fruits may well be satisfied if he produces varieties differing from any others hitherto in existence, even though these new varieties should not chance to be of superlative quality under general culture. Yet it might be your good fortune to produce a new fruit of distinction at the very outset. In any event, you may without question improve the quality of any fruit in your garden if you will follow the methods that Mr. Burbank has developed. You may grow better berries than you ever grew before, and different ones from those of your neighbor, with no great effort—once you know how.

NEW VARIETIES TO ORDER

The production of new varieties of genuine importance lies well within your grasp if you are willing to take the slight trouble involved in hybridizing different species of small fruits—followed by rigorous and persistent selection. For that matter, it is not necessary to do pollenizing, as the pioneer work has already been done with most of our small fruits, and selection alone, systematically followed up, will bring interesting results. Mr. Burbank's remarkable Himalaya berry was produced by selection, from seeds imported from India.

Should you wish to stimulate further variation, however, you may practice cross-pollenizing. The method has been explained in connection with orchard fruits, and need not be repeated here. The only essential, it will be recalled, is the transfer of pollen from one flower to the pistil of another at a time when the pistil is mature, or approaching maturity.

The fruit in itself that grows from the flower thus cross-fertilized will not reveal the character of the pollen parent. If, for example, pollen has been brought from a blackberry flower to fertilize a raspberry, the raspberry fruit will be the same in appearance as it would have been if the flower had been fertilized with pollen from another raspberry.

But the seeds in the fruit will be profoundly changed in nature, though in no way altered in exterior appearance, and the vines that grow from them next season may show at once the evidence of their hybridity. Just what will be the character of the fruit they will bear can never be predicted, and this uncertainty gives added interest to the experiment.

As a rule, it is well in hybridizing two plants to make what is called a reciprocal cross—that is to say, use pollen from each plant to fertilize flowers of the other plant. But it is the general experience that the hybrid offspring have the same characteristics whichever way the cross is made.

CULTIVATING THE FRUIT ORCHARDS

The view is taken at Sebastopol. It shows modern fruit trees trained to such manner of growth that they permit the plow to run close to their trunks. This is an experimental orchard, and the trees are planted closer than they would be in a commercial orchard, giving opportunity for abundant selection.

Mr. Burbank's experiments show that it is possible to effect hybridization between all the different varieties of blackberries and raspberries, and that interesting new varieties are produced in almost endless profusion. There is perhaps no other field that offers a readier opportunity for interesting experiments. Anyone who has a few bearing plants of the blackberry or raspberry in his garden has an equipment adequate for all his needs.

If you have plants of a single variety only, you may readily secure pollen of another variety from the plants of a neighbor, and thus an experiment may be inaugurated that is almost certain later to produce fascinating developments.

It is even within the possibilities that you may produce a berry as unique and remarkable as Mr. Burbank's Primus or his Phenomenal or his Himalaya. Short of that, you are certain to develop hybrid forms that differ in some respect from either parent. And the novelty of having a berry that is different from anything ever seen before will be adequate reward for the comparatively small effort involved.

It is stimulative to recall that the Loganberry, representing a new type of fruit that has found its way into thousands of gardens, was a chance hybrid between a raspberry and a blackberry cross-fertilized by the bees. If an insect can thus create a remarkable new species, what may not you hope to accomplish?

SOME PRACTICAL HINTS

In developing a hybrid you must of course grow the plant from the seed—preferably planted fresh from the berry as already suggested. But when you have secured a plant that bears fruit of exceptional character, you may propagate it indefinitely by root division, or, as already stated, by tips or suckers.

Thus you may stock your garden with any new variety you develop, regardless of whether it will breed true from the seed. But of course if you wish to accomplish further improvement you must make further selection and grow other seedlings; and from this second selection after crossing your best results are likely to be obtained.

Variations appear only among seedlings,—except in rare cases of "bud sports,"—and variation is the basis of all plant improvement.

You will do well, then, to study the characteristics of the different plants in your garden, and select for further experiment those that show some variation that appeals to you,—prolific bearing, or early bearing, or large size of fruit, or deliciousness of flavor.

Whatever the quality, you may confidently expect that it will be reproduced and accentuated in *some* individuals of the progeny of the plant grown from the seed. By selecting the best of the offspring, in the same way, to furnish seed for yet another generation, you may presently develop a variety that has the particular quality in question as one of its most pronounced attributes—although the specimen with which your experiment began may have shown only the faintest trace of it.

You may thus develop a new flavor, for example. Or you may double or quadruple the size of the fruit. The secret of success is to select rigidly plants that show variation, and breed from them.

One very important thing to understand, however, is that your selection should be based not on an individual berry, but on the average product of a vine. A single fruit may chance to grow under exceptional circumstances—alone on a vine, or particularly favored by light or nourishment—and so may attain what might be called abnormal proportions. Such a fruit is not more likely to produce large progeny than the smallest, meanest fruit on the plant. It is heredity that counts, not the peculiarities of an individual plant.

But if you find a plant whose average product is larger than the ordinary, you may with confidence save the berries of that plant for seed, and you will almost surely get some seedlings that will bear berries even larger than those of the parent plant. Even if there is not much improvement in the first generation, there is likely to be a cumulative effect with successive generations, and a time will come when striking results will be apparent.

Mr. Burbank speaks of this cumulative tendency as "the momentum of variation." It has often given him remarkable new varieties suddenly, after a series of breeding experiments that for a time gave little promise. The ultimate product may differ so widely from the first form as fully to justify reference to it as a "new creation."

There is one other important point to be borne in mind in developing a quality through selection in the way just suggested: namely, that you must inbreed the plants that are developing the new quality, once the variation is manifest.

Suppose, for example, you have found a raspberry vine in your garden that bears fruit that is very large and of exceptional sweetness. You wish to accentuate these qualities. Now, instead of cross-fertilizing, you do just the opposite. You take pollen from a flower of your choice vine and carry it to the pistil of another flower on the same vine. Or you bring pollen from a closely related plant of similar qualities. This is called inbreeding, or "line breeding."

You must combine forces, as it were, and accentuate the quality that both parents present in exceptional degree. By cross-breeding (say at an earlier stage of the same experiment) you promoted variation, and laid the foundation for new varieties. By inbreeding you limit variation, accentuate a given quality, and fix a type,—turning the forces of the plant in the desired direction.

One method supplements the other, and Mr. Burbank's most successful experiments in plant development always include both methods.

BERRIES AND GARDEN FRUITS

MAKING A WHITE BLACKBERRY

Let us see the methods applied by Mr. Burbank in one or two typical experiments. Take, for instance, the case of the white blackberry. This is one of Mr. Burbank's most interesting (though not most useful) small-fruit developments. We may briefly trace its pedigree.

It appears that a small brownish-white blackberry was found growing wild in the eastern states, and introduced by a New Jersey firm a good many years ago as a curiosity, under the name of the Crystal White blackberry. Notwithstanding the name given it, the fruit was by no means white, and it was of very inferior quality as to size and flavor.

It occurred to Mr. Burbank, however, that he might be able to improve the quality of the fruit and remove its traces of brownish pigment.

In attempting to accomplish this, Mr. Burbank hybridized the little berry with the Lawton blackberry. The hybrid offspring all bore berries that were black in color. In the second generation, however, there appeared a small proportion of vines that bore fruit that was almost white, and yet was of fair quality.

These vines, being inbred, gave in the next generation berries that were pure white and of large size and excellent flavor.

What had happened, in effect, was that the good-fruiting qualities of one ancestor had been combined with the unpigmented fruit of another strain; and this was precisely the combination that the plant developer was seeking. Meantime the cross-breeds varied widely, and some of them showed a tendency to vigorous growth and prolific bearing. Of course, there were numberless others that showed undesirable combinations, but these were destroyed, and only the plants having the desired qualities in the best possible combination were preserved. By inbreeding these for a few generations, the new qualities were accentuated and fixed, and a race of white blackberries which always come true from the seed was established.

Let it be particularly noted here that the new berry, as finally developed by selection, combines the traits of two widely different ancestral strains and accentuates them, while eliminating other ancestral traits. It has the juiciness and sweetness of flavor of the Lawton blackberry; and it is snow-white, whereas one of its ancestors was black and the other a brownish-white. By selective breeding, all trace of pigment has been eliminated from the species.

It will be obvious that this selecting out of certain qualities from different ancestral strains and reassorting them in a hybrid progeny, with the elimination of other ancestral traits, is a very interesting and very remarkable phenomenon. Mr. Burbank early discovered that it is possible thus to segregate the qualities of different parents and recombine them, accentuated, in the hybrids of a second and a few subsequent generations. The application of this principle enabled him to produce a large number of his most important new varieties of all kinds of plants. He decides in advance what qualities he wishes to perpetuate and what ones he wishes to eliminate, and by selecting among large numbers of seedlings he is enabled to secure the ideal plant that he has in mind.

But it must not be supposed that Mr. Burbank's success is due merely to the recombining of desired fruit characters already present in one parent or the other. On the contrary, such segregation and recombination of traits constitutes only the beginning of his task. This does, indeed, supply him with varying material with which to work; but as a rule he would not produce a fruit of commercial value did he not extend the experiment by selective breeding among the individuals that have the desired quality in the most pronounced degree. Line breeding them intensifies these qualities; so that, for example, the Burbank white blackberry is snow-white, whereas its so-called "white" ancestor was dull brownish-white, and at the same time it has the excellent qualities of the Lawton.

THE THORNLESS BLACKBERRY

It was through application of the same principles that Mr. Burbank was enabled to develop his wonderful thornless blackberry, perhaps the most important of his plant developments in this particular field. Anyone who has had experience of a brier patch will readily conceive that the production of a thornless brier is a work of genuine importance.

Mr. Burbank's thornless blackberries, as already stated, have absolutely smooth stems. There is not the remnant of a thorn anywhere about them. They are as smooth as pussy-willows. They are the forerunners of a race of thornless brambles that will doubtless supplant the old thorny kind everywhere in the near future.

The parent form with which Mr. Burbank worked in producing these anomalous plants was a nearly thornless but otherwise worthless dewberry that was discovered growing wild in North Carolina. The botanist who discovered the plant gathered some of its fruit and sent it to Mr. Burbank, thinking he might care to experiment with it. The fruit in question was of poor quality and, as in the case of the white blackberry, it was necessary to breed altogether new qualities into it.

The problem, of course, was how to retain and accentuate the tendency to thornlessness of plant that was the sole recommendation of this particular variety of dewberry, and at the same time to place berries of good commercial qualities on these plants.

When the thornless dewberry was hybridized with other blackberries, the hybrid offspring were all thorny, just as the offspring of the black and the white blackberries were all black. But thornless progeny reappeared in the second generation, and some of these bore fruit of a better

THE PROCESS OF GRAFTING COMPLETED

After the scions are inserted, grafting wax is applied, and the end of the stock is bound up with cloth, to give it added protection while its wounds are healing.

quality than that of their thornless grandparent. By continuing the experiments in crossing and selection through successive generations, introducing the strains of various fruits of quality, new varieties were finally produced that bore fruit of large size and excellent flavor in great profusion, on vines that were thornless but which retained no other obvious quality of the thornless ancestor.

To understand fully the difficulties with which the experimenter had to contend, it must be understood that the thorny condition is prepotent or dominant, so that when a cross was made with a blackberry of quality (all of which had thorns) the offspring were all thorny, and it was necessary to inbreed these offspring to secure in the next generation a certain number that reverted to the thornless condition.

Thus the experiment had to be carried through a number of generations, alternating between thorny and thornless plants, and between plants bearing berries of quality, and those with nearly worthless fruit, until plants were finally produced that combined the quality of thornlessness with the capacity to produce excellent fruit.

Now that a thornless blackberry of quality has been developed, however, there is opportunity for further hybridizing experiments to produce new thornless varieties that have the qualities of the different blackberries and raspberries prized by the small-fruit gardener.

There is, for example, the enormously productive blackberry already referred to that was developed by Mr. Burbank from seed imported from India, and hence named the Himalaya berry. A single plant may produce several hundred pints of berries in a season. But the vine is armed with very stout recurved thorns, making the gathering of the berries a somewhat difficult and decidedly disagreeable task.

It should be possible by hybridizing this plant with the thornless blackberry to produce in a later generation a plant combining the vigorous growth and prolific bearing of the Himalaya with thornlessness. Mr. Burbank has made this cross, and he has also crossed the thornless blackberry with the white blackberry. He has many thousands of seedlings of both type now under test that will give new varieties of thornless berries when fully educated. He has also seedlings from a new cross of the Japanese Balloon-berry and a raspberry from Hawaii, and scores of other berry seedlings of new combinations.

It is not unlikely that in the course of these experiments there will develop berries with quite unpredicted qualities. For Mr. Burbank has shown over and over that where plants from widely separated geographical regions are brought together the offspring are likely to manifest extraordinary vigor, and to reveal traits of the most unexpected character.

The hybrid seedlings of the Balloon-berry and the Hawaiian raspberry grow so rapidly as soon to overshadow their parents. Such enhanced capacity for growth is shown by various of Mr.

Burbank's berry hybrids and often extends to the fruit itself, as in the case of the Primus berry and the Phenomenal berry, already noted.

So there is every prospect that any hybridizing experiments you may undertake with blackberries or raspberries in your garden will produce new races, a certain proportion of the individuals of which will excel the parent forms very markedly in vigor of growth and in size of fruit.

OTHER SMALL FRUITS THAT AWAIT DEVELOPMENT

Doubtless the blackberries and raspberries offer the most inviting opportunities for experiment, yet we must by no means overlook the other small fruits that are to be found in the amateur's garden. The strawberry, for example, may be hybridized quite as readily as the other berries. In particular it would be well worth while to repeat Mr. Burbank's experiment of cross-pollenizing the strawberry and the raspberry. A similar cross might be attempted with the blackberry, now that Mr. Burbank has developed a strawberry that bears throughout the season. Hitherto it would have been difficult to find strawberries and blackberries blossoming at the same time.

It is true that Mr. Burbank's celebrated experiment in crossing the strawberry and the raspberry produced only infertile hybrids. But it is quite within the possibilities that greater success might attend another series of experiments. And it requires no argument to show that a fruit that combines the qualities of the strawberry and the raspberry would be a very valuable and interesting acquisition.

If you will take the trouble to fertilize the flowers of the raspberry and blackberry with pollen of the strawberry (it would be well to make the reciprocal crosses also) it may fall to your lot to produce a fertile hybrid that will be as unique and remarkable an addition to the list of small fruits as is, for example, Mr. Burbank's plumcot among orchard fruits.

Again, we must not overlook the currants and gooseberries. These have small flowers, and hence are not quite so easy to work with. But with the aid of a magnifying-glass they may readily be cross-pollenized, and there is ample opportunity for the development of new varieties. It is particularly desirable, for example, that gooseberries should be developed that are without the disagreeable hairs or prickles that most varieties of this fruit bear, also without thorns on the bushes. A sweet and high-flavored gooseberry would also be welcomed. Plants that are resistant to mildew are also to be desired.

Mr. Burbank has shown that the different currants and gooseberries may be cross-fertilized readily. There are numerous varieties under cultivation that may be used in hybridizing experiments, and there are also wild species to be found in many regions that might advantageously be tested. In many cases a wild species has qualities of hardiness and vigorous growth that may advantageously be blended with the size and flavor of fruit of the cultivated varieties.

So it might be possible, by hybridizing the currants and gooseberries with wild species, to produce new types of berries that would retain the attractive qualities of the currant, yet would be as large, let us say, as cherries. Here again the field is one that any amateur may readily enter, now that Mr. Burbank has shown the way.

A few years ago it would have been thought ridiculous to suggest that our common fruits might thus be modified and developed into new forms with comparative little effort, and in the course of two or three generations. But Mr. Burbank has shown that such modifications may be brought about, making the demonstration thousands of times over, until no opportunity for skepticism remains. And, as already suggested, there is perhaps no other field that offers more inviting opportunities than those that are to be found in the ordinary small-fruit garden.

SOME NEW FRUITS

As illustrating the possibility of making additions to the list of garden fruits, mention may be made of Mr. Burbank's sunberry, which is a hybrid between two forms of nightshade, neither of which produces edible fruit.

This new berry, which is particularly prized for the making of pies,—it closely resembles the blueberry in flavor,—is a brand-new addition to the list of edible fruits. It was produced as a fixed new species in the first generation, through hybridizing two forms of nightshade; one of them from Africa, the other a weed-like plant indigenous to America or long ago introduced from Europe. The hybrid is in a good many ways intermediate between the parent forms, but it differs from either of them in that its berries are edible.

Some confusion has arisen through the change of name, unauthorized by Mr. Burbank, which led to the placing of this fruit on the market as the "Wonderberry," and through the confusion of the new fruit with other species of nightshade to which it is only distantly related. The nightshade family, it should be explained, has poisonous members, and so is of ill repute. But it should not be forgotten that among the wholesome representatives of the family are the familiar garden vegetables, the potato, the tomato, and the eggplant.

From the standpoint of the plant developer, perhaps the chiefest interest associated with the sunberry hinges on the fact that the hybridization through which it was created was accomplished only after many years of unsuccessful effort. Indeed, Mr. Burbank had attempted to cross-fertilize the parent forms, quite without success, for something like twenty-five years, before he at last succeeded in fertilizing a single flower and producing a single berry from which the new race was developed.

Mr. Burbank is constantly experimenting with other wild plants that have more or less inedible fruits. He has in recent years conducted a very elaborate series of investigations with different varieties of elder, and is developing varieties that produce berries very much improved in size and quality. He is confident of producing a valuable commercial fruit, and the fact that the elder is a hardy ornamental shrub gives added value to the experiment.

Another line of experiment that promises good results is being made with the different species of passion flower. This subtropical vine has been chiefly prized for its flower, but it bears a fruit that is edible, and the quality of this fruit is being improved by cross-breeding experiments in which species from different parts of the world are utilized.

THE MOST PROLIFIC FRUIT-BEARER

But by far the greatest of Mr. Burbank's recent triumphs in the production of new fruits is that associated with the development of the fruit of the cactus, and in particular those new hybrid cactuses of the genus *Opuntia* that have been relieved of their spines.

The development of the spineless cactus through a long series of experiments in hybridizing and selection constitutes one of the most remarkable of Mr. Burbank's achievements in recent years. The slabs of the perfected varieties are as smooth as the palm of the hand, and they constitute a remarkable addition to the world's forage crop, particularly adapted to arid regions.

While developing these spineless races, Mr. Burbank paid attention to the fruit as well, and he has developed many varieties of cactus fruit varying in appearance and quality almost as widely as do the different varieties of cultivated apples or pears. Some of the cactus fruits are white in color, others yellow, yet others a brilliant crimson. The flesh is juicy and palatable. As yet the prickles have not been entirely removed from the skin of the fruit, but Mr. Burbank has plants now under development that he is confident will bear perfectly smooth fruit. It required a little longer to take the spines off the fruit, because the cactus does not bear fruit until it is four or five years old, and it was necessary to let each succeeding generation come to maturity before the quality of its fruit could be determined.

Meantime the prickly or smooth condition of the slabs of the plant could be observed from the outset, and selection for this quality could be made while the seedlings were very small. But in the end the spines will be removed from the fruit as effectively as they have been removed from the foliage of the plant; such, at any rate, is Mr. Burbank's confident expectation.

In the size of its product, the cactus is to be compared with the orchard fruits rather than with the berries. But the cactus, in its perfected varieties, is admirably adapted for growth in the

A BRAND NEW BURBANK FRUIT—THE PLUMCOT.

This beautiful reproduction of a direct-color photograph shows one of the choice varieties of Mr. Burbank's new fruit, the Plumcot, produced by hybridizing the plum and the apricot, and representing the only new type of orchard fruit that has been developed within historic times.

garden, and it has many attractive qualities. It is enormously productive, thrives under the most adverse conditions, and bears a fruit so different from any other of the products of the garden as to have double attractiveness.

A single plant will bear all the fruit that a good-sized family could use. Sometimes half a hundred fruits are borne on a single slab. The best of Mr. Burbank's fruiting varieties bears, on good soil, at the rate of more than one hundred *tons* per acre.

Unfortunately the new fruiting cactus plants are not very hardy, but whoever lives in a region to which they are adapted will find this a valuable addition to the fruit garden. Meantime there is opportunity for further experiment in selective breeding with an eye to the production of hardier varieties.

There are varieties of cactus that thrive in the coldest regions, and it is probable that by using these in hybridizing experiments new varieties might be developed that combine the fruiting qualities of Mr. Burbank's new cactuses with the hardiness of the other parent. Mr. Burbank himself has experiments under way looking to this end, but there is no reason why his efforts should not be supplemented by those of many other workers.

The cactus is a comparatively easy plant to hybridize, its flowers being large and conspicuous. It is necessary, however, to watch the flowers closely and cross-fertilize them at once when they open, before the bees have time to forestall your efforts.

Except for the development of new varieties, the cactus should not be grown from the seed, as, like other cultivated fruit-bearers, it does not breed true. But the slabs take root readily,—especially if dried somewhat before planting,—and the plant may thus be propagated indefinitely, all the offshoots reproducing the qualities of the parent form.

CHAPTER VI

BURBANK IN THE VEGETABLE GARDEN

IN this chapter are detailed the methods of selective breeding through which improved types of vegetables of many kinds may be produced in your garden.

Among the most remarkable of Mr. Burbank's experiments were those in which he grafted tomato plants on roots of potatoes and potato vines on roots of tomato vines. The resulting fruits and tubers were extraordinary and unlike anything seen before. These experiments may be repeated by anyone who will follow out the comparatively simple methods of grafting described. The feat of hybridizing the blossoms of potato and tomato has not yet been accomplished, but this is among the possibilities, and the results are sure to be extraordinary.

The members of the squash and melon family offer interesting possibilities of hybridizing, and these experiments may easily be carried out by anyone. New types of peas and beans may readily be produced; and experiments of a fascinating character may be performed with various varieties of sweet corn. In fact, there is scarcely a plant in the vegetable garden that does not offer opportunities for interesting experiments.

THE BURBANK POTATO

Doubtless you have eaten the Burbank potato, although you may not know it by that name. Mr. Burbank developed this new variety when he was a very young man, and it has come to be grown so universally that most people who cultivate it know nothing of its origin. The Department of Agriculture estimated that up to 1906 not less than seventeen million dollars' worth of Burbank potatoes had been grown in the United States. This was Mr. Burbank's first important plant development, and for that reason also it has exceptional interest.

Unlike many of his later developments, the new potato was produced without the necessity for a long series of preliminary experiments. It was, in a sense, a discovery rather than a creation, and as such it has added interest for the amateur, inasmuch as it suggests the possibility of finding in any garden extraordinary things if only we search for them.

The extraordinary thing that Mr. Burbank found in his Massachusetts garden when he was scarcely more than a boy (it happened in 1873) was a seed ball growing on one of his potato vines.

Everyone knows that the potato is propagated by planting pieces of the tuber itself, and that ordinarily the potato vine does not produce seed. In very rare instances, however, a seed cluster does form, but it requires the imaginative mind of a Burbank to conceive that there is any importance in this exceptional phenomenon. Most gardeners would have paid no attention to the seed ball, but Mr. Burbank watched it attentively, and determined to find out what would happen if the seeds were planted. His plan was nearly frustrated by the loss of the seed ball, which was broken off by some boy or animal or by the wind just as it ripened. After patient search the treasure was recovered, however, and carefully preserved over winter.

There were twenty-three seeds in the cluster, and these were planted next spring, each one by itself, and the vines that grew from the seed were carefully cultivated.

In the fall, when the potatoes were dug, it was obvious that they represented twenty-three different varieties. No two hills were alike in size or appearance or abundance of their crop. And two of the hills bore potatoes of altogether exceptional size and quality. These were preserved and planted another season, and it was demonstrated that the tubers would reproduce their qualities, constituting a new variety, larger in size, whiter, smoother, and more uniform in shape than any existing variety.

To illustrate the element of chance that enters into the work of the plant developer, it may be added that whereas the remarkable Burbank potato was thus developed in a single season merely by planting seeds that developed quite independently of human effort, forty years of subsequent effort, in which vast numbers of hybridizing experiments have been performed, have failed to produce another variety of potato superior to the one that was virtually a gift of nature. In this field of endeavor, as in so many others, there is an element of uncertainty that adds to its charm.

Very recently, however, Mr. Burbank has experimented with wild species of potato from South America, and has produced some remarkable new varieties that are about to be introduced.

MAKING A PEA TO ORDER

As illustrating about as striking a contrast to the story of the potato as could be found, we might cite the story of the Empson pea.

Mr. Burbank was asked by a canner of peas to produce a new variety in which the individual peas would be small but uniform in size; in which they would be uniform as to number in the pod; and would mature at the same time, so that the entire crop could be gathered at once, it being the method in the modern cannery to cut the vines by machinery, carting them to the cannery like loads of hay. Of course it was essential that the peas should retain their quality of sweetness of flavor, and that the vines should bear an abundant crop of pods.

Mr. Burbank was able to meet these specifications in a period of only three years, by raising two crops of peas each season. And he did this purely by selection, raising large quantities of the vines, and searching attentively among them for the individual vine that bore a crop coming nearest to the specifications. All the other vines were destroyed, and the new races of peas finally developed were descendants of the one best vine. In each succeeding generation the inferior vines were similarly destroyed, and the best individual specimens preserved.

The vines of the sixth generation were practically uniform and met the specifications as to abundant crop of peas of designated size and quality, maturing at the same time.

But while Mr. Burbank was developing this new race of peas, he developed also from the same set of vines four other races, some of them bearing large peas, others lentil-shaped ones, merely by selecting generation after generation with these qualities in mind.

The point is simply that in any row of peas in your garden, grown from the same lot of seed, there is a wide range of variation, which the average gardener quite ignores.

But the attentive eye notes that some vines grow abundant crops and others scanty crops; that some of the pods are large and some small; and that as regards almost any given quality of the pea there is diversity, even though the peas are all classified as belonging to the same variety.

If you will select and save separately the peas from half a dozen different vines, you may develop as many different races of peas in the course of a few generations. You may produce a variety of predicted quality, as Mr. Burbank did in the case of the canning peas, or you may, as it were, follow where the peas lead you, and let the potentialities of the different varieties reveal themselves as you proceed.

SELECTION WITHOUT CROSSING

This important point must be borne in mind, however—and it applies not merely to peas but to all other plants. In making your selection, it is necessary to consider the total product of a given plant, not merely an individual fruit. A single pod of peas may be of exceptional size because it chanced that it is the only pod on a vine, or because some other accidental circumstance favored it. The progeny of these peas will not necessarily tend to produce a race of large peas. But if you find a vine that produces pods that are uniformly of large size, this will indicate that the tendency to produce peas of this character is in the heredity or germ-plasm of this particular vine, and will tend to be transmitted.

It should be observed that in producing these new varieties of peas Mr. Burbank worked purely by selection, without finding it necessary to hybridize the plants to produce new tendencies to variation.

The plants tended to vary sufficiently to give him material for his experiments, and such is found to be the case with a very large number of plants in the vegetable garden.

MR. BURBANK'S PHENOMENAL BERRY

This remarkable berry is virtually a new species produced by hybridizing the California dewberry and the Cuthbert blackberry.

Quite generally you will find that there is a wide range of variation in the plants grown from the same lot of seed, and you may develop new varieties merely by selecting those individuals that exhibit the desired quality, saving their seed and selecting again for the same quality among the progeny.

In the case of the pea, and its cousin the bean, the experiment is simplified by the fact that the plants are normally self-fertilized. If you will examine the flower of the pea or bean you will see that its stamen and pistil are encased in a closed floral envelope, to the interior of which bees and other insects cannot readily gain access. Normally each pistil is fertilized by pollen from the stamens that grow beside it.

In other words, there is the closest inbreeding, and there is no danger of introducing varying strains of other plants by cross-fertilization.

The case is radically different, for example, from that of the squashes and melons, which are so readily cross-fertilized that it is exceedingly difficult to keep the strains of any variety pure if other varieties are grown anywhere in the neighborhood. The bees are almost certain to carry the pollen of one kind of melon or squash to the pistil of another, bringing the pollen perhaps from flowers a quarter of a mile away; so you will experience constant disappointment in growing crops of melons or squashes from the seed, unless you carefully shield the blossom from such contamination through cross-pollenizing.

If you wish to keep your strain of melons or squashes pure, you should carry pollen from one flower to another with the finger tip or with a camel's-hair brush, and then cover the flowers with a paper sack until they are past the time of receptivity.

On the other hand, if you wish to experiment with varying races of melons or squashes, you have but to leave the work of cross-fertilization to the bees, and your seeds next season will give you as strange and variant a lot of material as you could desire. But there is no such difficulty with the peas and beans. These, as just stated, are protected against cross-fertilization by the character of their flower, and thus it is comparatively easy to maintain a pure strain, once it is established.

HYBRIDIZING PEAS AND BEANS

If you wish, however, to extend your experiments with peas and beans, causing them to vary and thus to supply new material for selection, you may readily do so by the method of artificial pollenation. For although the floral envelope is closed against the bee, you may readily enough open it, and the pollenizing of the flower then presents no difficulties. You may pluck away the stamens and deposit pollen from another flower on the pistil, precisely as you would do in the case of any other blossom.

Tie a string loosely about the stem on which this blossom grows, with a label naming the variety used as the pollen parent, and preserve the seeds for planting next season.

Some of the most interesting and important plant experiments have been made with the garden pea in this way, notably the celebrated experiments of the Austrian monk, Mendel, which led to his discovery that some characters are "dominant" and others "recessive" in heredity, and that the recessive characters reappear in a certain number of the progeny of the second generation.

Mendel found, for example, that if a pea grown on a tall vine was hybridized with one grown on a short vine, the progeny of the first generation would all be tall,—tallness of vine being "dominant." But the recessive trait of shortness, although submerged in the hybrid of the first generation, will appear in one individual in four of the offspring of the second generation. It is obvious that the fact that the flowers are self-fertilized simplifies the experiment, insuring that the hybrids shall be inbred, and preventing the introduction of new hereditary strains that might complicate the results.

Some of Mr. Burbank's earliest experiments were made with different varieties of beans. For example, he hybridized two varieties of bean, one of which produced a crimson pod with red beans and the other a crimson-and-white-striped pod with red-and-white-striped seed. Curiously enough, the hybrid beans were jet black in color, unlike either parent. But in the succeeding generation the offspring of the black bean broke up into new groups, some of them producing black beans, some red, some speckled, and some white. There were corresponding variations as to size and shape of the beans, and as to time of ripening.

Meantime the hybrid vines showed the enhanced vitality that is somewhat characteristic of hybrids. They grew enormously, outstripping their parent by eight or ten feet.

But the vines of the second generation were extraordinarily diversified, some of them growing with great vigor and others being dwarfed, and of such stocky growth that their pods trailed the ground.

In another experiment Mr. Burbank hybridized the pole bean and the lima bean, and the hybrid showed at first the characteristics of both parents, but subsequently took on the form of the pole bean. Mr. Burbank notes that this case is somewhat comparable to that in which he hybridized the strawberry and the raspberry. In that case the vines were at first like the strawberry, and then shot up like raspberry plants. The case of the hybrid beans that showed both gigantic and dwarfed progeny in the second generation is comparable to that of Mr. Burbank's hybrid walnuts, in which some individuals of the second generation grew ten times as fast as others.

In more recent years Mr. Burbank has hybridized many varieties of beans, and has found it feasible to segregate and recombine the traits of different varieties in almost any desired combination.

By hybridizing and selection he has been able "to put the pod of one bean on the vine of another," somewhat as Mendel did with his peas. He has operated with about forty varieties of beans, and has produced new combinations almost infinite in number. No plant, he says, can present greater surprises or wider diversity among the hybrid progeny. And he thinks that the bean offers as many inducements for improvement as any other plant under cultivation. It is a plant that should prove peculiarly attractive to the amateur.

Many varieties of beans are available, and they may be grown readily in any corner of the vegetable garden. If you will hybridize almost any varieties that are at hand, you may be sure of interesting results next season.

EXPERIMENTS WITH SWEET CORN

Another plant with which you may experiment with full assurance of interesting results is the sweet corn.

If you have chanced to grow in your gardens two varieties of corn, one having yellow kernels and the other white, you have probably noticed ears that were mixed, bearing partly white and partly yellow kernels.

These were the product of cross-breeding experiments performed for you by the wind.

And had you chosen to do so you might have carried the experiments further and been witness of the application of some very fascinating principles of heredity. Now that your attention is called to it, you will do well to take the matter into your own hands and forego the assistance of the wind in the particular experiments in question.

The pollen of the corn, as you doubtless know, is borne in the tassel at the top of the stalk. The pistillate flowers are borne on the stalk itself, and their presence is indicated by the putting out of the familiar wisps of so-called silk, each strand of which is in reality a pistil that leads to the egg cell, which, if fertilized, will become a kernel of corn.

Under ordinary conditions the pollen sifts through the air and is dusted over the silky pistils, its germinal nucleus making its way along the substance of the tenuous pistil to the egg cell. If there are different varieties of corn growing in the same neighborhood, cross-fertilization is almost certain to occur.

In the case of most kinds of plants, cross-fertilization does not affect the appearance of the immediate fruit, but shows its effect in the plants that grow from the seed.

But corn is anomalous in this regard, for the kernel shows at once the influence of the foreign pollen.

If, for example, the pistils of the variety of corn that ordinarily bears white kernels are fertilized with pollen from a yellow variety, the kernels will be yellow, because this color is "dominant," in the Mendelian sense. And if part of the pistils receives pollen from the yellow variety and part from the white variety, the resulting ear may be variegated, some kernels being yellow and some white. Thus you may know at once whether cross-pollenation has been effected.

This obviously gives a clew to some interesting possibilities of experiment.

You might, for example, apply pollen from two or three different varieties of corn to different parts of the silky tassel. You will thus secure an ear of corn that is a conglomerate of different strains of heredity.

There are other qualities beside color that may be considered. For example, some varieties of corn have more starch, others more sugar. The starchy kernels are plump, the sugary kernels wrinkled when mature. Starchiness is dominant to the other condition; so the kernels fertilized by the starchy variety will be plump, in contrast to the wrinkled sugary ones.

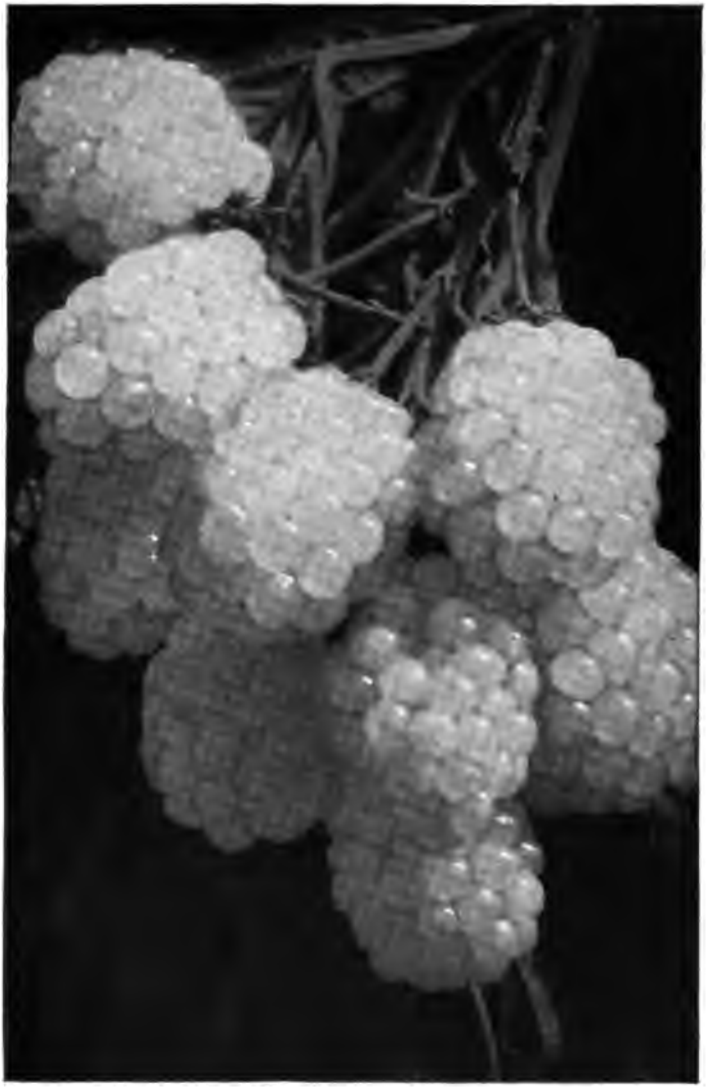
It is obvious that interesting combinations are possible if you hybridize, let us say, a variety having starchy white kernels with one having sweet yellow ones.

The immediate result of this particular combination would be that all the kernels of an ear thus cross-pollenized would be plump and yellow. But if these kernels are planted, the crop grown from them next season (if self-fertilized) will show interesting varieties and recombinations of the various qualities. There will be some kernels that are plump and yellow, others that are plump and white; some that are wrinkled and yellow, others that are wrinkled and white.

And there is exceptional interest in the fact that these different types of kernels may appear on the same ear, and that they will exist in a predictable mathematical proportion. In accordance with Mendelian principles there will be three yellow kernels to one white, and three plump ones to one wrinkled. But further breeding experiments would show that two out of three plump kernels carry the wrinkled condition as a recessive trait, and that two out of three of the yellow ones carry whiteness as a recessive trait. This can be proved by planting the kernels and observing their progeny in another season.

The experiment thus carried out will come to have the fascination of a game of chance, but unlike most games of chance, it will well repay the effort bestowed upon it.

Incidentally, in the course of such an experiment, you will probably be able to develop new varieties of sweet corn that will meet with approval on the table, at the same time that you are finding entertainment in a game at heredity in which you co-operate with nature and direct her forces.



MR. BURBANK'S WHITE BLACKBERRY.

This remarkable variety was produced by crossbreeding and selection. It is now a thoroughly fixed variety, coming true from the seed. If such a fruit were found in a state of nature it would unhesitatingly be pronounced a distinct species.

IN THE VEGETABLE GARDEN

MODERN CORN AND ITS ANCESTRY

Mr. Burbank in the early day of his work as a gardener devised a method of forcing sweet corn in such a way as to bring it to market ten days or so in advance of the ordinary time of maturing. The method consisted of generating the seeds in the greenhouse and then planting them after they had formed roots and sprouts an inch or more in length. No attention was paid to the way in which the little plants fell into the drills or furrows in which they were planted. They were simply dropped in as kernels of corn would be dropped, and covered with a thin layer of soil.

Sometimes they continued to grow so rapidly that they would be found pressing through the soil the next morning; and this start caused the plant to outstrip others that were grown from the seed in the ordinary way.

In recent years Mr. Burbank has experimented very extensively with corn, in particular with the primitive type known as teosinte, a giant form of grass indigenous to Mexico. This plant bears a head that is more like a head of wheat than like an ear of corn. But by selective breeding and hybridization Mr. Burbank has been able to produce all gradations between this primitive type of corn and the familiar cultivated varieties. He has thus virtually demonstrated that the cultivated corn is descended from teosinte.

It is possible by selective breeding to increase the size of the cornstalk, and to cause the ears to be borne at any desired height from the ground. Mr. Burbank has developed a variety of corn, for example, that bears its ears at such a height that a man can scarcely reach them. Such a variety has no commercial value, but was developed for its scientific interest.

You may amuse yourself by developing from the same stalk a variety of corn bearing the ears at the height of five or six feet and another variety bearing them only a foot from the ground. Such a series of experiments has been carried out successfully by the Agricultural Experiment Station of Minnesota. It is possible also to modify the chemical composition of the corn, increasing or decreasing its protein content.

Such experiments, aside from their possible practical value, have a high degree of interest, and they fall readily within the scope of the operations of the amateur who has even the smallest garden at his disposal.

Another interesting variation has to do with color of leaf of the corn plant. By selective breeding, Mr. Burbank has produced a variety called rainbow corn because of the striping of the leaves. He now contemplates combining this with sweet corn of good quality, so that the plant may combine ornamental quality with practical utility.

COMBINING POTATO AND TOMATO

Experiments of a totally different kind that may lead to even more fascinating results may be performed with the potato and the tomato, along the lines of an experiment first made a good many years ago by Mr. Burbank. This consists of grafting the stem of the tomato plant on the roots of the potato, and, contrariwise, the stem of the potato on the roots of the tomato.

The process of grafting is not unlike that of grafting twigs on a tree, consisting essentially of bringing the cut surfaces of the two stems in close and accurate contact, and binding them together until union is effected. The stems should be of the same size, and it will be well to notch them in such a way that they fit accurately together. The experiment will not be successful in every case, but the interesting results of a single success will compensate for many failures.

In Mr. Burbank's experiments the potatoes grown on vines having tomato tops were curiously distorted in shape, and some of them had a rough and scaly surface. The leaves of the tomato were seemingly not able to produce just the right kind of material for the manufacture of normal potatoes, yet they performed their vicarious function better than might have been expected, considering that under normal conditions they are called on to produce material for something so widely different from the potato as the familiar fruit of the tomato.

Perhaps it should be explained that the leaf of a plant contains the laboratory in which carbonic acid from the atmosphere is compounded with water to form the organic sugars and starches that are the original basis for the building of living matter. The starch of the potato is not manufactured in the ground, but in the leaf of the potato vine, whence it is transmitted in the form of a soluble sugar to the root, and there transformed into starch and deposit in the tuber.

This must be understood if one would appreciate the unwonted task to which the tomato tops were called when they found themselves joined to the stem of a potato plant.

When the combination was made the other way, the tomato roots proved unable to develop the capacity to form tubers, but the potato tops retained their tendency to develop material for the manufacture of tubers.

So a compromise was effected by growing the potato not underground on the roots of the tomato, but in the air, from the axils of the leaves of the potato plant.

A potato vine grafted on tomato roots and decorated with aërial potatoes is surely an anomaly that would excite interest in any garden. Mr. Burbank has shown us how to produce this anomaly, and there is no reason why the experiment should not be repeated. It is true that no permanent vegetable of value has been developed in this way, but the experiment has interest that fully justifies it, quite aside from any question of practicality.

It is possible, moreover, that plants thus grafted might be more susceptible of hybridization, and that a new and important vegetable might be produced by hybridizing the flowers of the potato and tomato. Hitherto Mr. Burbank has been unable to effect this hybridization, although he has many times attempted it. But he is foremost to proclaim that such negative experiments are never final.

The case of the sunberry—produced after twenty-five years of fruitless effort—among others taught him that one may succeed at last in hybridizing two species that have refused to unite in thousands of earlier experiments. It is well known that as a rule plants that cannot be hybridized cannot be successfully grafted. So the fact that potato and tomato may be grafted is in itself evidence of the probable feasibility of hybridizing the two under proper conditions.

Any amateur may raise a few tomato vines and a few potatoes and the transfer of pollen from one to the other may readily be effected. Should fertilization result, the hybrid combining the strains of the potato and tomato is sure to be a plant of exceptional interest, and not unlikely it will prove a valuable addition to the list of garden vegetables. At all events, the attempt to effect this hybridization is worth half an hour of your time.

If you were to succeed where Mr. Burbank has failed, your feat would indeed be worth recording. Even though you fail of your main purpose, the effort will at least afford you an interesting study in the anatomy of flowers.

VARIED OPPORTUNITIES

The foregoing instances will serve to guide you in experiments that may be applied to all the remaining products of the vegetable garden.

Whatever the vegetable to which you pay attention, you will discover that there is a considerable range of variation among different specimens of the same variety. By selecting for seed purposes the specimens that present in the fullest measure the quality that you desire to accentuate, you will at once be on the track of the development of new and improved varieties.

If in any case you find that the plants do not vary in the direction in which you think there might be improvement, you may adopt the expedient of cross-pollenizing the flowers, uniting different varieties of the same species or individuals of closely related species.

You may, for example, cross-fertilize different varieties of onions, or you may hybridize the onion with the leek or the chive.

Mr. Burbank has produced numberless new varieties of the onion family by hybridizing its different members. Some of these have beautiful blossoms, and some have bulbs of extraordinary size. The Burbank pink chive, for example, is a decorative border flower as well as a palatable table vegetable. And there are beds of his hybrid onions that take fairly high rank in the flower garden.

Meantime he has developed varieties of the

Spanish onion with bulbs weighing three or four pounds.

He states that the various members of this family are easy to work with by way of selection, and that the only difficulty in hybridizing them is due to their small flowers, and may readily be overcome by the use of reasonable care. Whether by hybridizing or by mere selection, he says, the onion is susceptible of great improvement along various lines,—size, flavor, decrease of odor,—and the ease with which it may be cultivated especially commends it to the amateur.

In recent years Mr. Burbank has made extensive experiments in developing the artichoke, a vegetable that is exceedingly popular in Europe, but which until recently has been somewhat neglected in America. The artichoke is a composite flower; that is to say, it belongs to the family of which the sunflower furnishes the type, and which is characterized by growing a large number of flowers in a single head, surrounded by a row of petal-like rays. In cross-fertilizing flowers of this type, Mr. Burbank is accustomed to wash away the pollen with a stream of water from a garden hose before applying the head of another flower and rubbing the two flower heads gently together to effect pollenization.

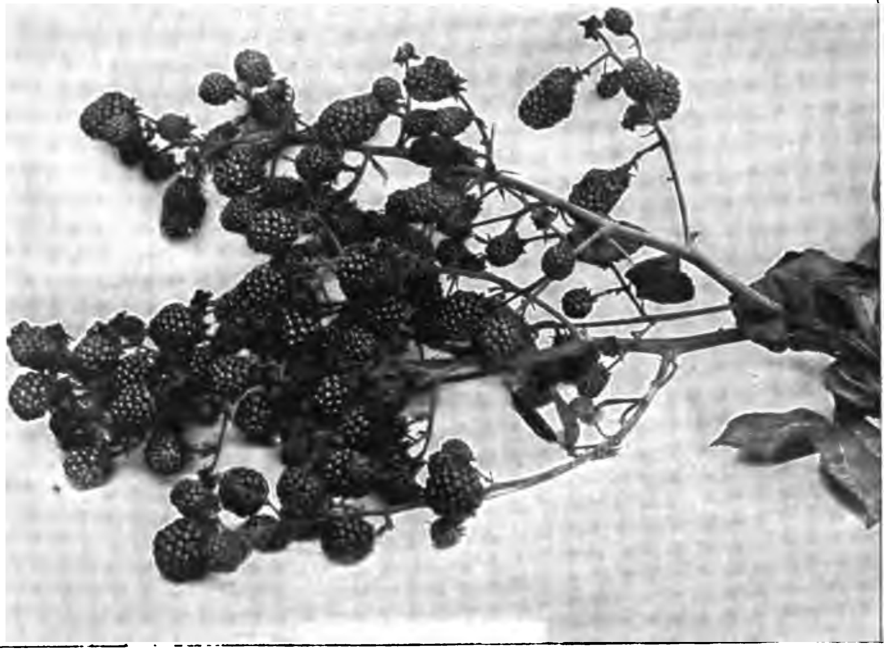
The part of the artichoke that is eaten is the flower head itself, the protecting bracts of which have developed a pulpy portion at their base. The receptacle on which the flowers grow, known as the heart of the artichoke, is also edible. But the flower must be plucked before it opens, as it is inedible after coming to maturity.

By crossing various varieties of the European artichoke, and by selective breeding, Mr. Burbank has developed new varieties that are exceedingly large, the flower heads being more than two feet in circumference when open. The mature flower, with its mass of blue flurries, is so attractive that it is sometimes allowed to open and picked for ornamental purposes.

The artichoke has been so little worked with that it offers good opportunities for the amateur, either through cross-breeding or merely through selection. Plants grown from the seed are sure to show a certain range of variation, and you may readily develop improved varieties by selecting seeds from the best and repeating the selection through two or three successive generations.

Parsley, the mints, the mustards, cabbages, turnips, peppers—all of these have been worked with extensively by Mr. Burbank, and all have possibilities of development that make them attractive for the amateur.

Another vegetable with which one of Mr. Burbank's greatest triumphs has been effected is the winter rhubarb, which came from New Zealand with a stem scarcely larger than a lead pencil, but which has now been developed until it is of gigantic size, and which has taken on the habit of perpetual bearing. The latter habit is explained, in part at least, by the fact that the rhubarb came from another hemisphere. Summer



THE BURBANK THORNLESS BLACKBERRY

The stem of this plant is as soft as a pussy willow. The berries are of large size and of excellent quality. The plant is the cross-bred and selected descendant of a wild partially thornless dewberry, that in itself was of no importance.

in New Zealand is of course our winter time, and vice versa, and the plant found it difficult to adjust itself to the new order of seasons. By encouraging it to maintain its old system of reckoning in the new latitude, Mr. Burbank made it practically a perpetual bearer. It is at its best in the winter season, when ordinarily rhubarb is altogether dormant.

Another important line of experiment to which Mr. Burbank has devoted much time and attention has to do with the introduction of new races of garden vegetables. He has worked with a species of lily called the camassia, which bears beautiful flowers, until its bulb gives promise of rivaling the potato. He is similarly educating another lily called the brodiæa; and yet another known as the tigridia—a bearer of beautiful flowers; and he has even turned attention to such hitherto unwelcome plants as the dandelion, the thistle, and the burdock, all of which he believes are likely candidates for admission to the vegetable garden.

The bulb of the tigridia is regarded by Mr. Burbank as the most delicious of vegetables when cooked.

Sundry tropical solanums—relatives of the potato and tomato—are being relieved of their spines and educated to bear better fruits by Mr. Burbank. The ground cherry and the passion flower are other plants that he has in training, the fruits of which have already made significant progress. In the further development of these plants, and a good many others, any amateur who chooses to master the technique of plant experimentation may take a hand, and there are few fields that offer better opportunities for the employment of leisure half-hours.

Viewed in this light, the vegetable garden becomes a maze of fascinating and beckoning mysteries.

CHAPTER VII

BURBANK IN THE FLOWER GARDEN

THIS chapter describes Mr. Burbank's method of mating the flowers with an eye to the production of new varieties, and the methods of selective breeding through which the colors and forms of blossoms may be developed.

Almost any flower may be improved in size, changed in form, made double, or altered in color. Mr. Burbank has made hundreds of such modifications in the case of flowers from all parts of the world, including both the common garden varieties and the rarest exotics.

The exact method by which these changes are wrought is here described,—how, for example, the Shasta daisy was developed, the scented calla, the blue poppy, the crimson eschscholtzia, and numerous others. Typical illustrations are given as to each of the different methods of procedure, and the entire process is so clearly described that the amateur may produce similar results if he will intelligently follow the directions given.

You may have flowers different from those of your neighbor, and, indeed, different from any that have ever been seen before, if you are willing to take the trouble to develop them. And it will appear that in many cases new developments may be brought forth rapidly. In dealing with flowers, you are not required to wait for a term of years, as you sometimes would be in developing new races of orchard fruits. For this reason, and also because of the great variety of interests that attach to flowers, the amateur may very well begin his experiments in the flower garden.

In undertaking the improvement of a flower, one may have in mind the form of the blossom, its size, profusion of bearing, color, or odor. Mr. Burbank's work furnishes almost countless illustrations of improvement in regard to all of these qualities, sometimes singly, sometimes in combination.

Of course the simplest type of experiment is that in which a single quality is under consideration. Such a case as that of Mr. Burbank's scented calla furnishes a typical illustration.

The calla, as everyone knows, is ordinarily quite without a pleasing fragrance; if it has any odor at all it is a slightly disagreeable one. But the variety of calla developed by Mr. Burbank and introduced under the name of Fragrance has a delicious perfume that adds very greatly to the attractiveness of this beautiful flower, and Mr. Burbank tells us that this quality of fragrance was developed in the calla in the course of three generations of selective breeding, without hybridization.

WHY FLOWERS HAVE PERFUME

Most readers are probably aware that—according to accepted theory—the perfume of flowers in general has been developed through natural selection as an aid in attracting insects, on which the plant depends for cross-fertilization. We human beings have come to enjoy the fragrance of the rose and the apple blossom, and we are sometimes egotistical enough to suppose that these perfumes were developed for our delectation.

But the botanist assures us that, so far as the wild flowers are concerned, man's tastes were not in the least consulted in the development of either color or fragrance.

The development of scented and beautiful flowers was the work of sundry insects, of which the bee is most important. The colored petals of the flower and the perfume that it exhales are advertisements addressed to the bee, intended to guide him to the nectary within the tube of the flower, in approaching which the insect will unconsciously come in contact with the pollen-bearing stamens, and in due course transfer the pollen from one flower to another.

When, therefore, we find a flower like the calla that is devoid of fragrance, we may feel pretty certain that this flower is not habitually fertilized by the bee, but depends upon some other agency.

In the case of the calla, the agents that effect cross-fertilization are sundry small gnats and flies that find the tubular canopy a welcome shelter at night. This white canopy is really a modified leaf and is called by the botanist a spathe. The essential organs of the flower are distributed on the central column called a spadix, and are exceedingly inconspicuous. The upper portion of the spadix bears the pollen, and the lower portion is the pistillate surface. But the two parts do not mature at the same time, so self-fertilization does not take place as would otherwise be inevitable.

It has been found by experiment that the air inside the tubular spathe is somewhat warmer than the outside air. So it is not strange that insects should gather here, and they naturally come in contact with the pollen, and carry it to other flowers that they subsequently visit. The whiteness of the calla suggests that it is designed to attract night-roving insects, the white flower being more conspicuous at night than a brightly colored one.

MAKING A FRAGRANT CALLA

It is not unlikely that some ancestors of the calla depended on the bee for cross-fertilization, and hence were fragrant. Otherwise it is hard to account for the appearance in Mr. Burbank's colony of callas of an individual that had a faint but appreciable perfume.

Whatever the explanation, such an anomaly did appear a good many years ago, and Mr. Burbank detected its presence and at once decided that this flower was worthy of cultivation. He carefully saved the seed of this individual, and watched the development of the progeny with solicitude. Most of them were quite odorless. But there were a few that reproduced the fragrance of their parent, and one of these was more distinctly fragrant than the original.

The seeds of this specimen were saved in turn, and among the plants that grew from them were several that were distinctly fragrant, and, as before, one that conspicuously excelled the others. Indeed, the perfume had now been so accentuated that this individual was as fragrant as could be desired. The plant was propagated by dividing the roots, after the usual method, and soon a company of callas was produced, all of which duplicated the qualities of the parent form. This was the flower that was sent out under the name of Fragrance.

The process of development of the scented calla, then, consisted in raising seedlings from an individual that showed a trace of perfume and selecting in turn through successive generations the individual that had inherited this quality in largest measure.

But the most interesting feature of the experiment was the fact that the quality, although not transmitted to most of the progeny, was accentuated in the case of the individual to which it was transmitted.

And this, fortunately, is typical. Wherever a flower shows a peculiarity that differentiates it from its fellows, this peculiarity may be accentuated or exaggerated by selective breeding. And sometimes the development is gratifyingly rapid.

NEW COLORS IN THE POPPY

As another illustration of this, take the case of Mr. Burbank's crimson California poppy, named by the botanist Eschscholtzia.

This flower in its wild state is of a brilliant orange color, but one day Mr. Burbank discovered a specimen that showed a thin line of crimson running up the center of one petal. The seeds of this poppy were carefully preserved, and among the plants that grew from them one was discovered that had a flower with a slightly wider line of crimson.

The next generation showed farther progress in the same direction, and presently a poppy had been produced the petals of which were crimson throughout.

There was no necessity for hybridization or for any directive manipulation. All that was necessary was to preserve and sow the seed of the plant that showed the tendency to vary, and thus to give the new color an opportunity to assert itself.

In this case the crimson color appeared, as just related, as a narrow but conspicuous line. There are other cases in which a new color appears only as a modified tone, readily overlooked by the casual observer. Such a case was that of the

INSPECTING HYBRID BLACKBERRIES

Mr. Burbank (at the right) is discussing with Dr. Williams the results of an experiment in crossing the thornless blackberry with various other selected varieties.

flower from which Mr. Burbank developed his celebrated blue poppy.

The flower that showed the original tendency to variation was a Shirley poppy, the red color of which lacked a little of its usual beauty. To Mr. Burbank's discerning eye there seemed a certain smokiness of hue that suggested possibilities of variation. So of course the seeds of this poppy were carefully preserved. In the next generation there were a few individuals that showed a more conspicuous smokiness of color; and in the course of three or four more generations individuals appeared that had flowers distinctly bluish in hue. This bluish quality was further accentuated in succeeding generations, until a poppy appeared that was of a clear pale-blue color.

There is no record that anyone ever saw a pure blue poppy before, yet the materials for blue pigmentation were evidently hidden in the germplasm of the poppy, and selective breeding removed the obscuring elements and enabled the blue color to make itself manifest. The principles of selective breeding employed were simple to the last degree; yet through their application a flower was produced that is marvelously transformed.

Another curious and interesting color modification was effected in Mr. Burbank's "silver-lining" poppy. The original flower was crimson with a black center. A specimen appeared that showed a white line between the black center and the crimson petal. By selective breeding this line was widened generation after generation, until the flower was white with black center; the white extending just over the outer edge of the poppy, the rest of the backs of the petals remaining crimson.

CHANGING A LEAF

It is not the blossom alone that may thus be modified by selective breeding. Other parts of the plant may be similarly transformed. A striking illustration of this is furnished by a leaf modification that Mr. Burbank brought about in the case of the California plant sometimes called "wild geranium," known to the botanist as heuchera.

This plant usually has a fairly smooth leaf with an indented edge, not unlike that of the ordinary cultivated geranium. But Mr. Burbank once chanced upon a specimen growing wild that showed a tendency to crinkling of the edge of the leaf.

He transferred this plant to his garden, saved its seed, and searched among the progeny for an individual that reproduced the anomaly of leaf formation. As expected, some individuals were found that not only reproduced but accentuated the anomaly. And in succeeding generations individuals appeared in which the peculiarity was so accentuated that ultimately the leaf became crinkled and crenated over practically its entire surface, losing all resemblance to the normal form and appearance.

The plant that showed this peculiarity resembled the wild parent form as to blossom and general habit. But its leaves were so modified as to constitute a new variety to which a specific name has been given.

Hundreds of other instances might be cited in which Mr. Burbank has modified the quality of stem or leaf or flower of a familiar or unfamiliar plant by this process of selective breeding, in which a "spontaneous" tendency to variation supplied the material with which the experimenter worked. It is rare indeed for a plant to come under his observation in which he does not detect some indication of what to his keen perception seems a bid for improvement.

If you will carefully examine any group of flowers in your garden, you will at once see that no two plants of the same variety are precisely alike; and if you wish to accentuate any observed variation, you may undertake the task with full confidence, if you will follow out the method just outlined. In some cases progress will be rapid, in others slow, but you are almost certain to see some improvement among the progeny of the first generation, and not unfrequently you may detect a very marked transformation in size or form or color, or in any other quality for which you are selecting, in the course of two or three generations.

The fact appears to be that every individual plant is the center of many conflicting hereditary currents. Selective breeding singles out a tendency and gives it an opportunity to manifest its possibilities. By this method alone you may develop any number of new varieties of flowers in your garden with an insignificant expenditure of time and effort.

All that is necessary is clearly to grasp the principle of selective breeding, and to search diligently in each successive generation for the individual that shows the strongest tendency to vary in the desired direction.

CONSTRUCTING A NEW SPECIES

But while remarkable transformations may thus be effected by mere selective breeding, it will be understood, of course, that with the flowering plants, as with fruits and vegetables, it may often be desirable to give an added stimulus to variation through the hybridizing of different species, or the crossing of marked varieties. Indeed, this is the usual method through which striking new varieties have all along been developed in Mr. Burbank's garden. Even where selective breeding, along the lines thus described, is used to accentuate or fix a variation, there has very commonly been a preliminary series of experiments in which variation has been stimulated through hybridization.

Mr. Burbank early discovered that new varieties may be produced by this method, and the persistent application of the method to countless species of plants laid the foundation for his conspicuous successes. Beautiful ixias, for example, were thus developed, and marvelous hollyhocks; also new races of tritonias, and numberless new and extraordinary varieties of starflowers, lilies, watsonias, petunias, larkspurs, marigolds, sunflowers, and scores of others.

As a typical illustration of what he has been able to accomplish in this field, we may cite the case of the Shasta daisy.

This remarkable flower has for one of its ancestors the little ox-eye daisy familiar everywhere throughout the eastern United States. This flower was hybridized with the European daisy, the strains of two subspecies or marked varieties being introduced. Selective breeding among these hybrids produced a flower that was much larger than either of the parent forms and in many ways more graceful and beautiful.

But the flower was not of as pure a white as Mr. Burbank desired, and to improve it in this regard, as well as to give it fresh tendency to variation, he crossed the hybrid form with a Japanese daisy that had a small flower of dazzling whiteness. The progeny showed the expected tendency to variation, and some of them combined the whiteness of the Japanese parent with the large size and attractive qualities of the American-European hybrid. By selective breeding numerous new types were developed, some of them bearing flowers not far from six inches in diameter.

The new flower that thus combined the racial strains of three species was itself so different from any one of the parent forms that it would be regarded by any botanist who found it in the wild state as a unique species. It is, in short, a new species of daisy created by artificial selection under the hand of the plant developer. It was named the Shasta daisy.

Various series of experiments in selective breeding have developed numerous varieties of Shastas, some having broad flat ray flowers, others thin and fimbriated or tubular ones, yet others being partially double. In a word, the Shasta daisy is not only a new form of flower, but one that has developed numberless varieties, comparable, therefore, with various other types of cultivated flowers. Yet there was no such thing as a Shasta daisy in existence until Mr. Burbank combined the different species from Europe, America, and Japan, and thus gave opportunity for the blending of hereditary factors that had their origin in the environing conditions of three continents.

The case of the Shasta daisy, then, may be taken as typifying the second of the two important methods through which the plant developer operates,—the method of hybridization.

Of course the perfected Shasta represents also the use of the other method, that of selective breeding. Indeed, the two methods go hand in hand, each supplementing the other. Taken together, they constitute the basis of a complete method of plant development, and through their application all the possible transformations that may be brought about in a limited period of time may bė effected.

QUANTITY PRODUCTION

Of course your task will be facilitated if you raise large numbers of individual plants. Part of Mr. Burbank's phenomenal success is due to the scale on which he operates. He raises individuals of a given variety not merely by thousands, but by hundreds of thousands or millions. Nor is a large territory required for these operations, particularly in the case of flowering plants, because great numbers of these can be raised in a plot a few feet square, and only the most satisfactory specimens are preserved in each succeeding generation.

As an instance of the rigorous selection through which Mr. Burbank's flowers are improved, it may be related that on one occasion he destroyed eight cords of bulbs of the South African plant called the watsonia, preserving only a few specimens that were the superlative ones among the hundreds of thousands.

It may be asked why Mr. Burbank destroys these bulbs, when he might readily sell them.

The answer is that the bulbs represent an intermediate stage of development, and as has been pointed out in another connection, if they were allowed to go out they would be advertised presently by some unscrupulous person in a way to mislead the public and do injustice to the plant developer himself. Mr. Burbank never allows a new plant creation of any kind to be introduced unless he is thoroughly convinced that it is equal in all respects to any similar variety already on the market, and superior in at least one respect. Until the new variety can meet this test, it is still in the experimental stage, and only a few of the most promising specimens are preserved, the others being ruthlessly sent to the bonfire.

To the observer who sees hundreds of thousands of the plants bearing really beautiful flowers thus destroyed each year at Santa Rosa and Sebastopol the method seems ruthless; but it is an inevitable concomitant of the comprehensive plan through which so many wonderful varieties of flowers, vegetables, and fruits have been developed in Mr. Burbank's experiment gardens.

Among the most interesting of the plant colonies that have been produced in countless galaxies to supply Mr. Burbank with material for selection are such familiar flowers as the lilies and poppies.

HALF A MILLION NEW LILIES

Mr. Burbank's experiments with lilies were carried out on a most comprehensive scale for many years. He hybridized all the exotic species and varieties that seemed to promise favorable results, until he had the most extraordinary collection of lilies, doubtless, that ever existed anywhere in the world,—"here a plant six feet high with yellow

MR. BURBANK'S HIMALAYA BLACKBERRY

The picture suggests the remarkable growth of this plant, the ancestors of which were brought by Mr. Burbank from Asia. A single plant of this remarkable variety may produce more than a hundred pints of berries in a season.

flowers beside one only six inches high with dark red flowers, and farther on one of pale straw or snowy white or with curious dots and shadings; some deliciously fragrant, others faintly so; some with upright, others with nodding flowers; some with dark-green woolly leaves or whorls or with polished, light-green, lance-like scattered leaves."

In one of his early announcements, Mr. Burbank spoke of having "half a million kinds of lilies yet to unfold their petals for the first time," adding that he was still planting from one to three pounds of hybridized lily seed every season.

"Search this earth all over," he said, "climb every mountain, plunge into every cañon, valley, and jungle; and, when all this is done, visit every park, garden, nursery, and conservatory; go anywhere, everywhere, and as many varieties of charming lilies cannot be found as I have produced. All the earth is not adorned with so many new ones as are growing at my establishment."

It was pointed out that these hybrid lilies were crosses of parents selected for health, hardiness, easy management, and rapid multiplication, as well as for fragrance, beauty of coloring, grace, and abundance of flowers; and the justifiable assertion was made that "in these hybrids a broad foundation has been laid for endless varieties which will reward lovers of flowers for ages to come."

A glance at the photographic reproductions that accompanied the announcement justified the plant developer's enthusiasm.

STRANGE HYBRID POPPIES

As to the poppies, the results of hybridizing in Mr. Burbank's hands have been no less extraordinary. Some of his most interesting results have attended the crossing of the opium poppy with sundry varieties of the Oriental poppy. Rather curiously he found that the pollen of the opium poppy was ineffective when used on the Oriental, yet when the reciprocal cross was made, the pollen of the Oriental being used on the opium poppy, seed was produced, and a great number of hybrids were soon under observation.

The hybrid colony comprised more than thirty thousand plants, including many extraordinary forms. For example, the hybrid poppies sometimes produced enormous seed capsules, five or six times as large as the ordinary seed capsule of either parent. Yet in other plants the seed capsule would be small; in still others twin capsules were produced; and with numerous others there was not even the intimation of a capsule, the flowering stem ending abruptly like the end of a lead pencil. And even where the capsule was large, the seeds were produced in much diminished quantity, and were shriveled and shrunken in size.

The plants grown from these seeds—second-generation hybrids—were extraordinarily variable. Mr. Burbank declares that he has seldom seen a more remarkable company of plants. "The diversity was so great that it might be said there were no two plants among the thousands that were even approximately identical."

The foliage in particular was amazingly varied. There were long, smooth, strap-shaped leaves, and short stubby ones; smooth, glossy leaves, and rough, hairy ones; leaves like those of one or the other of the parent forms; and nondescript leaves that variously suggested the primrose, cherry, dock, wormwood, dandelion, and scores of others.

The blossoms were not only diversified in color, and some of them enormously increased in size, but they showed a curious modification, in that they were produced at all seasons instead of only for a short period, as is the habit with the parent species.

The first-generation hybrids themselves were perennial plants (although their mother plant was an annual), and they bloomed persistently. "There is not a day in the year when some of these hybrids are not in bloom at Sebastopol, spring, summer, autumn, or winter—blossoms can always be gathered in quantity from them."

It is of peculiar interest to note that the second-generation hybrids were in part annuals, like one of their grandparents, and in part perennials, like the other grandparent. The annual and perennial habit appear to be a pair of Mendelian unit characters of which the perennial habit was "dominant" and the annual habit "recessive"; there being a characteristic segregation in the second generation.

The possibility of producing almost endless numbers of new varieties of poppies from such a conglomerate company is obvious. The difficulties are greater than might appear, however, because of the tendency to sterility. Many hybrids show greatly increased fecundity, but with these poppies this is reversed, the reason being, perhaps, that the plants are almost at the limits of affinity, beyond which cross-fertilization would be impossible.

THE ORIGIN OF SPECIES

It should be understood that hybridization and selection are natural methods, and that in using them man is merely imitating on a small scale the practice by which nature has brought about the evolution of all the existing forms of plant and animal life. Plants in the state of nature are frequently hybridized through the agency of insects, or by the wind in the case of those who do not depend upon insects for cross-pollenation.

Mr. Burbank cites numerous instances of natural hybrids that he has observed; for example, the madia plant, or tarweed, two species of which frequently hybridize; mints of various species; the wild raspberry; and the different species of hickory nut.

He believes that such natural hybrids afford the material from which new species are constantly being developed through natural selection, and the results achieved by Mr. Burbank himself in the development of new species by this method go far to substantiate his belief. He habitually hybridizes species, and develops new races by artificial selection.

About the only difference between this method and nature's method is that in the wild state the characteristics that are likely to be preserved through natural selection are those that are advantageous to the individual plant that manifests them; whereas under conditions of artificial selection the plant developer considers not the needs of the individual plant, but the tastes and needs of men.

Perfume is developed in Mr. Burbank's calla, for example, and in his fragrant petunias and verbenas, not because this is of advantage to the plants themselves, but because the perfume is pleasing to human nostrils. Similarly the blue color of the poppy is to please the human eye, the crinkled leaf of the geranium to satisfy a human taste for the bizarre, and the varied forms of the Shasta daisy to gratify esthetic human sensibilities.

Natural selection would have eliminated rather than preserved the variations in question; but civilized man creates a new environment and molds the forms of vegetable and animal life to fit that environment. The results are different because the conditions are different. But the principles of development are the same, and it may fairly be said that the plant developer in applying the method of hybridization and artificial selection is duplicating nature's method, and illustrating on a small scale the principles of evolution through which all living organisms have been developed.

In making practical application of these methods in the flower garden, you may select whatever plants are found there, almost at random. There is no race of cultivated flowers that does not offer opportunities for improvement through hybridization and selection. Of course you must work, in any given experiment, with species that are not too widely separated; otherwise your efforts at hybridization will be futile. You cannot hope, for example, to hybridize a rose and a dahlia. But you may hybridize the different species of roses among themselves or one dahlia with another, and in either case you will be fairly certain to produce forms that are different in some regard from the parent forms, offering opportunity for further improvement by selection.

But although, as a rule, plants cannot be hybridized unless somewhat closely related, experiment may reveal unexpected affinities, even between species belonging to different genera. Mr. Burbank has made a large number of very wide crosses, some of which have already been referred to. The interesting hybrid between the tobacco and the petunia may be recalled as an instance in point.

The curious plants that resulted from this union were some of them of upright growth like the tobacco, others of trailing habit like the petunia. It was said of them facetiously that they were petunias that had acquired the tobacco habit. Unfortunately they seemed incapable of forming a good root system and hence they lacked vitality. Mr. Burbank has since regretted that he did not graft them on tobacco roots, as in that way they might perhaps have been preserved.

It would be well worth while for someone to try the experiment over again, carrying out this suggestion.

PRODUCING AND FIXING NEW VARIETIES

It will be recalled that Darwin based his celebrated hypothesis of natural selection on the observed fact that plants and animals in a state of nature vary. He spoke of this variation as "spontaneous," thereby confessedly begging the question. Mr. Burbank believes that in a large number of cases such "spontaneous" variation is in reality due to hybridization. In the same way he explains the occurrence of those variations which, because of their wide departure from the parent form, have been described as "mutants."

The case of the mutants was brought prominently to the attention of the biological world a few years ago by Professor Hugo De Vries, the celebrated Amsterdam botanist. His observations were chiefly made with the evening primrose, and he founded on these observations the theory of evolution by mutation,—that is, by sudden vaults, —as a modification of the theory of evolution by the accumulation of minute changes.

Professor De Vries was unable to explain the cause of the mutation; but Mr. Burbank at once declared his belief that the celebrated evening primrose with which Professor De Vries had worked was really a hybrid, and this explanation is now coming to be pretty generally accepted.

Certain it is that Mr. Burbank has produced mutants without number in the course of his experiments through the process of hybridization,—a mutant being described as a form that departs radically from the type of its seed parent. The particular mutants that first attracted the attention of Professor De Vries bred true to the new type from seed, thus seeming to constitute a new race. The same thing is true of many of the mutants that Mr. Burbank has produced by hybridization. But as to this point, there is opportunity for diversity of habit. A new form produced by hybridization may breed true, as in the case of Mr. Burbank's Primus berry, but it is much more likely, as we have seen illustrated, to show a great diversity of form among its immediate progeny. Some of these forms may breed true, while others will fail to do so.

This is of the utmost importance to the plant developer, particularly in the case of annual plants that must be grown from seed. In the case of plants that can be reproduced by division the matter is not so important, as any new variety developed may be propagated indefinitely without use of the seed. Such is the regular method of propagation, as we have seen, in the case of the

MR. BURBANK INSPECTING GARLIC SEEDLINGS

The plants are specially cross-bred and selected specimens, having peculiar qualities of thrifty growth, as well as exceptional flavor.

orchard fruits, of such vegetables as the potato, and of bulbous plants in general.

But a large number of our flowering plants are annuals that are reproduced solely by the seed. With these it is obviously a matter of great importance that the seedlings should reproduce the qualities of the parent, otherwise the new variety that you produce would have no permanency.

It is precisely here that the patience of the plant developer is most often put to a test. Very generally the new variety that you develop by hybridization, and which you would wish to perpetuate, does not breed true from the seed. It becomes necessary, then, in order that your new variety shall have real importance, that you should practice systematic selective line breeding until you "fix" the desired quality or qualities.

To this end, you must sow the seed of your selected variety, and permit all the seedlings to mature. Among the hundreds of plants, there will probably be a few that reproduce the attractive qualities of the parent. The best of these should be carefully inbred—self-fertilized—and its seed sown next season; and a similar selection followed up, year after year, if need be, until a plant is secured all the seed of which will reproduce the desired quality.

If a single quality is in question, you will generally be able to "fix" the type in two generations. But if several new qualities are combined in your favored variety, it may be necessary to carry out the selective line breeding for five or six generations. Much depends on whether the qualities under observation act as "dominant" or as "recessive" qualities in the Mendelian sense. The exact meaning of this and the manner of testing have already been explained, and will be further elaborated in another connection.

The prime essential, however, is that the plants shall be rigidly guarded against cross-fertilization. New varieties are *created* by cross-pollenizing; they are *fixed* by self-pollenizing. In a carefully conducted experiment, it will be well to cover the plant with a net, to keep the bees from interfering, meantime hand-pollenizing each blossom with pollen from other flowers of the same plant.

METHODS OF POLLENIZING

In order to carry out this all-important business of pollenizing (cross-breeding in some cases, inbreeding in others), it will obviously be necessary to study the anatomical structure of different flowers. The principle is always the same—pollen from one flower is to be carried to the pistil of another. But some flowers have the stamens arranged in a peculiar way, and the casual inspector may not at first glance recognize them.

Plants of the iris tribe, for example, have a peculiar mechanism whereby the pollen is deposited on the back of a bee, and then is scraped off by the pistil of the next flower that the bee visits. The amateur botanist might not at first glance recognize the pistil, and hence might be puzzled as to the way in which pollenation is to be effected.

Again, the milkweed has its pollen in sacks arranged like saddle-bags, designed to entangle the legs of the bee, and the amateur might not recognize them as bearers of pollen.

A little study of the mechanism of the different flowers with the aid of a magnifying-glass will solve all of these difficulties.

Meantime the insight that will thus be gained into the curious modifications of structure through which nature guards against the self-fertilization of the flower will prove a source of perennial interest. Theoretical botany and practical plant development go hand in hand, and the flower garden is the ideal place to make initial studies of one and practical tests of the other.

CHAPTER VIII

THEORY AND PRACTICE

I HAVE all along attempted to make it clear that the fundamental principles of plant breeding are simple, and that the amateur may begin experiments and even carry them to interesting conclusions with comparative ease. It is desirable now to supplement what has previously been said by calling attention to some of the complications that are sure to arise as the work of plant breeding progresses; and in so doing, of course, to point out clearly how these complications may be met.

Let us first recall what has been outlined in the previous articles as to Mendelian heredity. We saw that when the flower of a tall pea vine is fertilized with pollen from the flower of a short pea vine the progeny will all be tall; but that in the second generation one vine in four will be short, like one of the grandparents. Thus in the vine of the first filial generation the hereditary factors for tallness may be said to be "dominant," since they make themselves manifest, and the factors for shortness may be said to be "recessive," since they are submerged and for the time being inoperative. But these recessive factors come to the surface, as it were, in one in four, on the average, of the progeny of the next generation. And it is observed that the short vine in which the recessive factor thus again makes itself manifest will breed true to shortness, the factors for tallness apparently being altogether eliminated from its germ-plasm.

Meantime, as just noted, for every short vine of this second filial generation there are three tall ones; and further breeding tests will show that, while these three vines look just alike, there are fundamental differences in their germ-plasm; for one of them will breed true to tallness (being a pure dominant, as the saying is), while the other two are "mixed dominants" and will have progeny of which, in each group of four, one will be short (pure recessive), one tall (pure dominant), and two also tall but of mixed germ-plasm like their parents.

The essential point is simply that any character that acts as recessive in the Mendelian sense will be seemingly eliminated in the first-generation cross that brings it in combination with the opposite character; but that the recessive character will reappear in the next generation, and will then breed true. So when you find that you are dealing with a recessive quality, you may fix it in the third generation without difficulty. But the dominant quality, on the other hand, although it makes itself manifest in all the first-generation progeny, and in three out of four of the second-generation progeny, has to meet the masked rivalry of recessive factors in two out of three of its second-generation members, so that these cannot breed true.

When you wish to fix a dominant quality, therefore, you must save the seed of each individual and plant it in separate plots. Only in this way can you determine which individual is a pure dominant, and hence will breed true. If you mix the seeds of your dominants, you may go on for generations, groping blindly in the effort to fix a new race, without success.

It is highly important to get these relations of dominant and recessive factors in Mendelian heredity clearly in mind. Indeed, the principle that mutually exclusive pairs of qualities are independently segregated and redistributed in the second generation of a hybrid progeny doubtless exceeds in importance all other aspects of the problem of plant development. It was through independent discovery of this law of heredity that Mr. Burbank was enabled to make the major part of his conquests in the domain of practical plant breeding.

DEALING WITH COMPLEX FACTORS

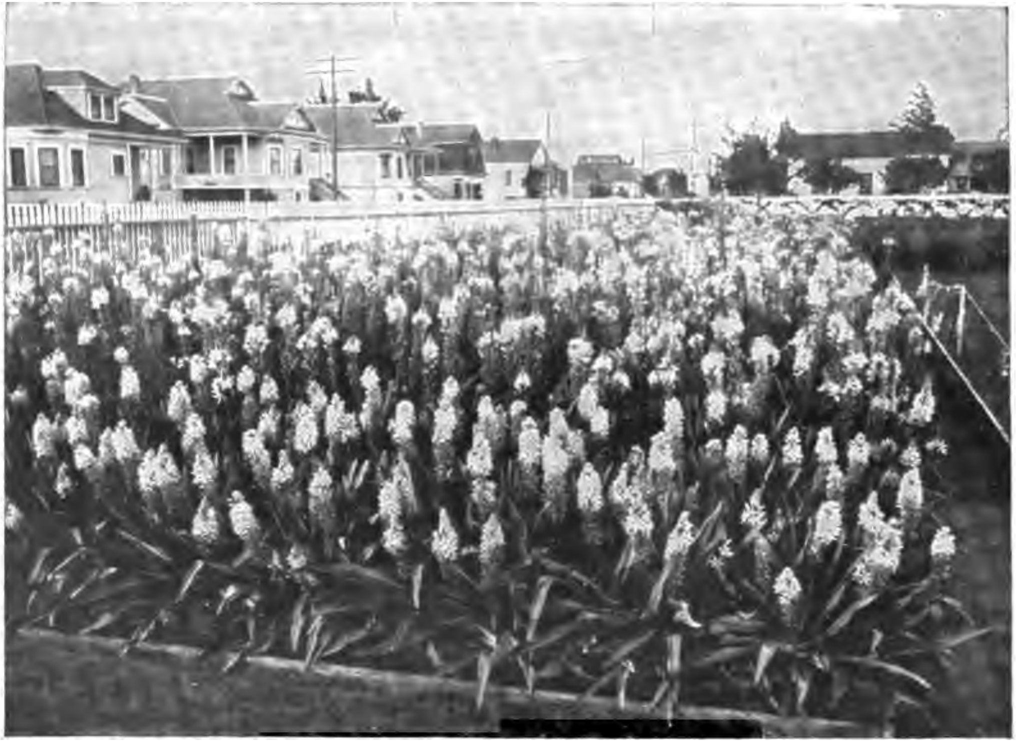
If you have grasped the essential principles of this Mendelian inheritance, your effort to combine the qualities of two different varieties of species of plant will represent a comparatively simple experiment so long as you have only one or two characters in mind. Suppose, by way of illustration, that you have in your garden a gladiolus with robust stalk that bears small flowers, and another variety with small stalk that bears large flowers. By crossing the two, and then inbreeding the cross-bred progeny, you may expect that in the second generation you will secure some plants that will bear large flowers on robust stalks, combining the good traits of the grandparents.

But, as your experiments are extended, you will presently be confronted with instances in which the case is not so simple. You will be concerned not merely with the size of stalk and size of flower of your gladiolus, but with questions of color, of abundant bearing, and of keeping qualities as well. And you should know that with the inclusion of each new character the application of the Mendelian formula becomes increasingly complicated. The fundamental principle, as just outlined, is not altered, to be sure. Each pair of qualities (tall stalk *versus* short stalk, large flower *versus* small flower, red flower *versus* white flower, etc.) will be carried forward quite independently of all the other characters, and recessive traits will tend to reappear in one individual in four of the second-generation progeny. But, according to the simple law of chances, it comes about that where two pairs of Mendelian factors are in question the recessive factors, although appearing in one individual in four of the progeny, will be combined *in the same individual* in only one case in sixteen.

And when three pairs of hereditary factors are in question—for example, tall or short vines, pink or white flowers, and yellow or green pods, in the case of Mendel's peas—the chance that the three successive qualities will be combined in the same individual of the second-generation progeny is only one in sixty-four. When four qualities are under consideration, the chance that they will be combined in any particular way is but one in two hundred and fifty-six. And with the inclusion of still other qualities, the geometrical ratio progresses in such startling fashion as to give us assurance that if we are attempting to combine ten different qualities in any given combination, the chance of doing so is about one in a million.

Your first thought will be, perhaps, that you are not likely to consider more than two or three qualities as desirable in the case of any given plant. But a moment's reflection will show that here you are in error. Let us, for example, consider the perfected varieties of gladioli that have been developed in Mr. Burbank's experiment gardens. We shall find that there is scarcely a quality of bulb or stalk or flower that has not been modified in one direction or another.

The bulb has been made to produce bulblets rapidly; they have been rendered hardy; and in particular they have been made relatively immune to disease. The stalks have been caused to grow to gigantic size, to stand firmly erect, and to bear flowers not merely on one side, as they were formerly wont to do, but in spirals that show the flowers in a solid cluster, the blossoms facing in all directions. The flowers themselves have been very markedly increased in size, and given bril-



THE CAMASSIA—A FLOWERING FOOD PLANT

Mr. Burbank has developed this plant until its bulb is a fair substitute for the potato. In the meantime the blossoms are highly ornamental, as the picture shows.

liancy of coloration and remarkable keeping qualities. Some of them have been made to bear double rows of petals.

Here, then, it appears that not fewer than ten separate and distinct qualities of the gladiolus plant have been under consideration in the course of Mr. Burbank's experiments. It is obvious that the plant breeder could not be satisfied unless the good qualities were all combined in the same individual plant. It would not at all suffice that one plant should have a hardy bulb while bearing poor flowers; or that another plant should have a splendid array of flowers on a frail stalk; or, again, that flowers of great beauty should have poor keeping quality. All the good qualities must be combined in the same individual.

Suppose that Mr. Burbank started with one gladiolus plant having a splendid stalk, another having an immune bulb, a third with flowers of large size, a fourth with flowers of good keeping quality, etc. He could combine the plants two and two by cross-pollenizing; and, by recombining again and again, in the fourth generation he would have blended the strains of all the ten original parents. But, as we have seen, the chance that any individual seedling of the next generation would combine the desirable traits of the ten original parent forms in just the right proportion is only one in a million.

That is why Mr. Burbank raises his seedlings in such immense profusion.

When the gladiolus experiments were under way, for example, you might see in his greenhouse box after box, each showing tens of thousands of gladiolus seedlings. Day after day the scrutiny of these multitudes of little plants is continued, the obvious weaklings being weeded out, until a fraction of the original number remained to be transplanted to the fields, and permitted to develop and reveal their possibilities. But even after all the obvious undesirables were eliminated, there would still remain hundreds of thousands of plants to be set out in long rows in the experiment garden at Sebastopol, each given equal opportunity with all the others. And, as we have seen, the ultimate result of the experiment would be the selection by Mr. Burbank at flowering time of perhaps a dozen or a score among all the hundreds of thousands as representing the closest approximation to the ideal type at which he aimed. Or perhaps a single plant would be found among the myriads that combined in fair measure all the good qualities that were sought. The experiment would then be completed by "line breeding" from this individual, saving all its seeds, and selecting among its progeny (which are sure to show a considerable range of variation) those that are best, until a race has been developed in which the desired qualities are accentuated to the maximum.

STUDIES IN COLOR VARIATION

Probably you could not do better in beginning your experiments with the ornamental plants of the dooryard than to work with reference to the modification of the color of the flowers.

There are numerous familiar plants with any one of which you might work to advantage,—for example, the gladiolus, the dahlia, the verbena, or the nasturtium. All of these plants show great color variation. In cross-breeding and selecting to secure new combinations of color, you are dealing with a restricted group of hereditary factors, and hence it will not be necessary to have large numbers of individual plants. Moreover, color in flowers is a new or recent development in the evolutionary sense, and hence modifications of color are more readily brought about than changes of root or stem or leaf.

It is probable that all flowers were originally green, and that in the course of evolutionary development some flowers changed from green to blue and then to indigo and violet, while others ran the chromatic scale in the other direction, varying from green through yellow and orange to red. Red and violet flowers are therefore probably new in the evolutionary sense, blue and yellow flowers being old. White flowers may be due to having air in their cells, or to the blending of other colors—say yellow and blue. Yellow flowers may be due to the blending of red and green. In general, the mixture of factors for color in the heredity of a flower may rival in complexity the mixture of pigments on the canvas of an artist.

The greatest interest of all, perhaps, for the amateur plant developer, attaches to the bringing out of unexpected colors that are submerged and hidden by more recently developed colors. As previously suggested, it is like the work of restoring an old masterpiece by removing the pigment of a modern painting overlying it.

It is at least a plausible theory that new qualities tend to be dominant and old qualities recessive in the Mendelian sense, when brought in opposition through cross-breeding. Generally speaking, then, it may be expected that in crossing a red flower with a white one of the same species the progeny will be red. Violet crossed with white usually gives violet. Between yellow and blue there may not be much to choose in point of date of origin, and the result of a crossing may be doubtful.

Any of the flowers mentioned may be worked with to advantage along these lines. An interesting wild flower showing similar possibilities is the Indian paint brush or painted cup (*Castilleia*). Specimens of this growing in the same neighborhood may vary from scarlet, crimson, orange, yellow, and purple to pure white. Even the same individual may show flowers having most of these colors. Mr. Burbank suggests that the amateur might advantageously work with the painted cup in an effort to remove the overlying colors and reveal the pure blue; also to fix the different colors in different races.

An interesting illustration of curious and unexpected results that may be attained is furnished by one of Mr. Burbank's hybrid pinks, in which the individual flower varies in color, changing from one shade to another in the course of twenty-four hours.

In the morning on first opening the flowers are pure white, by noon they are a bright pink, and toward evening they have changed to a deep crimson. All the flowers at present under consideration furnish illustrations of dominance of one color factor over another, and on occasion of the blending of factors to produce new colors; but this case in which first one color and then another is dominant in the same flower is altogether out of the ordinary.

ACCENTUATING DESIRED CHARACTERS

It remains to be said that the distribution of the various qualities of the plant into opposing couples showing dominance and recessiveness is by no means so clean-cut and explicit in every case as the instances just cited might lead one to expect. In point of fact, it appears to be true that it is only the qualities that are of comparatively recent origin in the evolutionary sense that clearly Mendelize. Such qualities, for example, as the precise length of stem, color of flower, and color of seed pod are far less fundamental than the essential qualities of form and anatomical structure of stem and leaf, and the shape and arrangement of the petals and the essential organs of the flower. When these fundamentals are in question, the hybrid progeny usually show a blending of the traits of the parents without clear dominance of one quality over another.

But even where these qualities are blended in the first generation, there is likely to be a segregation and redistribution along Mendelian lines in the second generation,—giving rise to the phenomenon which breeders have been accustomed to speak of as reversion in one direction or the other toward the parental types. So you will do well to be on the lookout for the phenomena of Mendelian heredity in the second generation, even where you fail to find clear evidence of the dominance of a character in the first hybrid generation.

If, for example, you were to cross an orange poppy and a white one, as Mr. Burbank once did, securing only crimson-flowered progeny, you could carry the experiment forward another generation with full confidence that there would be interesting color revelations, enabling you perhaps to analyze the component colors of the original parents in the second generation. In this particular case it is not unlikely that the original orange and white flowers contained blended pigments—perhaps red and yellow in one case, and yellow and blue in the other—and the breaking up and redistribution of these hereditary factors through cross-breeding might prepare the way for the bringing out of hidden colors, leading ultimately, perhaps, to the production of a blue poppy.

This illustration gives us a clew to yet another important aspect of our problem of plant breeding. In the main discussion of Mendelian heredity above, we have spoken as if the thing contemplated were the recombination of qualities that are already patent in one parent or the other of the original cross. But, in point of fact, the object sought by the plant breeder often goes far beyond the mere combination of existing qualities, as the case of the blue poppy at once suggests.

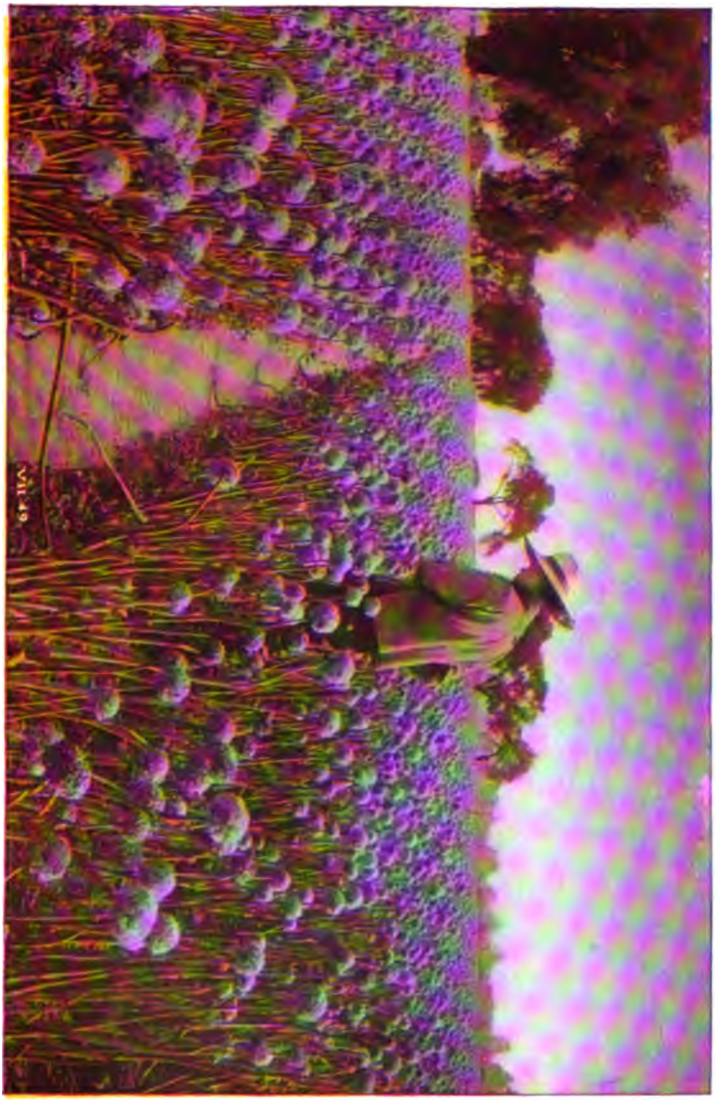
The same thing is illustrated by a beautiful blue gladiolus which Mr. Burbank developed by crossing an imported gladiolus having a small purplish flower with a large white one of his own development. The mingling of hereditary factors here gave new combinations, and ultimately produced a large flower from which the obscuring pigments had been removed, so that an underlying blue, recessive to most other pigments, was revealed.

It may be said that Mr. Burbank's plant developments have, as a rule, been similarly carried forward until qualities are so accentuated or modified as to seem of a quite different order from the qualities of the parent forms. Here, for example, is a giant amaryllis with a flower almost a foot in diameter, the product of experiments in hybridizing and selection that involved no parent plant having a flower more than five or six inches in diameter. Here is another hybrid amaryllis bulb which puts forth a new bulblet every week,—fifty of them in a year,—although the parent forms from which this variety was developed were accustomed to produce only half a dozen new bulblets in a season. Here is a hybrid between a crinum and an amaryllis, the bulb of which is far larger than a man's head, although neither parent had a bulb of unusual dimensions. And yonder is a hybrid gladiolus with a double row of petals, sprung from parents that bore flowers with no suggestion of doubleness.

UNEARTHING REMOTE HEREDITIES

In attempting to explain these anomalies, we are led to conclude that every individual plant carries in its germ-plasm a multitude of hereditary factors that are, as it were, submerged beneath other factors and prevented from making their presence tangibly manifest. There is apparently no limit to the number of generations through which a hereditary factor may be carried latent and seemingly impotent, yet always ready to manifest itself when the opportunity arises. And the opportunity may come through a hybridization that brings new coteries of hereditary factors into the combination, with resultant redistributions that no one could predict, but which may be very striking and highly suggestive and interesting in their manifestations.

The gigantic trumpet of the hybrid amaryllis and the enormous bulb of the hybrid crinum are reminiscent of past ages when remote ancestors of these plants grew under favoring tropical conditions of an earlier geographical era, and put forth flowers and bulbs of which the best present-



BURBANK ONIONS GROWN FOR SEED.

Mr. Burbank has worked extensively with the onion, as with numerous other members of the tribe of alliums. Here we see a field of perfected Burbank onions that have distinctly ornamental flowers. The excellent character of the bulbs may be inferred from the size and vigorous development of the tops.

day specimens are but dwarfed and insignificant replicas.

Similarly the double flowers that form so attractive a feature in our gardens—roses, dahlias, marigolds, and the rest—are probably reminiscent of clustered flowers of the antique world. What is now the composite head of a single dahlia or marigold or daisy was probably, in its primordial state, a cluster of flowers. Through natural selection such a cluster made an experiment in communism, in which finally hundreds of flowers were grouped, with a single circle of florets to advertise their location to the insects. This represented great economy, and the plan became enormously popular, so that the composites are among the most abundant of flowers. But each individual blossom in a composite flower head carries in its germ-plasm the factors for the development of an independent corolla, and under favoring conditions—through hybridization or through changed environment—this potentiality is realized in the production of what we term a double flower.

In this way only can we explain such a phenomenon as the rapid production of races of double dahlias in the relatively short period since the single dahlia was brought from Mexico and given a place in the cultivated flower garden.

CHAPTER IX

BURBANK'S METHOD OF BEAUTIFYING LAWN AND DOORYARD

THIS chapter tells how to apply Mr. Burbank's method to the care and beautification of the lawn and dooryard in their entirety. It deals not alone with the lawn itself, but with the bed flowers and ornamental vines that beautify the dooryard. Mr. Burbank has produced wonderful new flowering vines and numerous ornamental shrubs of great beauty. His work with the canna, gladiolus, watsonia, amaryllis, and rose has been as remarkable as almost any other work that he has done.

Many visitors to Mr. Burbank's home in Santa Rosa in recent years have been much interested in the lawn about his dwelling.

At a little distance this looked much like any other lawn that is well covered with grass. But closer inspection showed that the velvety covering was not made by grass, but by a trailing vine. It was in reality a species of verbena of a peculiar type. It is known to the botanist as Lippia, and this word serves as well as any other for a popular name.

Lippias of several species were sent to Mr. Burbank from Chile, and he has cultivated and developed two or three varieties with especial reference to their utility as substitutes for lawn grass. When Mr. Burbank first procured the seed of the wild species he observed a good deal of variation among the seedlings, and in the second season he raised about ten thousand plants, each one of which was given a little space in order that its individual peculiarities as to rapidity of growth, tendency to spread, and color of foliage might be tested.

From among these ten thousand plants about half a dozen were saved, and the descendants of these constitute several varieties of lippias that have striking peculiarities. One of these will spread on an ordinary soil over a circle about ten feet in diameter. This form, Mr. Burbank points out, would be very valuable for growing in sunny places, and in particular along irrigating ditches or river banks where the soil is subject to wash. Other varieties grow less rapidly, but have small leaves that lie very close to the ground, making a most beautiful and satisfactory velvety lawn.

There is a marked difference in color in the different varieties, so that charming contrasts may be produced by planting different portions of the lawn with different varieties.

In addition to their rapid and compact growth, Mr. Burbank's perfected lippias are adapted to dry soil, requiring not one-tenth the water that blue-grass or other ordinary lawn grass requires, and keeping in good condition with a fraction of the care that must be bestowed on lawns of blue-grass or clover.

Curiously enough the lippia lawn makes the best appearance where it is frequently trod upon and subjected to rough treatment.

All in all, then, the developed lippia constitutes a remarkable lawn cover, and one that must increase in popularity in all climates to which it is adapted. Unfortunately the plant is rather tender, and is likely to winter-kill in the northern parts of the United States. But it is expected that hardy varieties will be developed by further experiments in selective breeding, and the lippia will then become a formidable rival of the blue-grass for lawns everywhere, and in particular in regions where there are long periods of summer drought.

OTHER SUBSTITUTES FOR GRASS

Very recently Mr. Burbank has experimented successfully with several other substitutes for grass.

He has found two plants that are superior to the lippias for growth in soil subject to washing; for example, along creeks, or irrigating ditches, or on hillsides. One of these plants is a species of *Mesembryanthemum,* which grows along most seacoasts. This produces an enormous amount of dense foliage, which is not moved even by a very heavy stream of water.

The other plant is a selected variety of the trailing myrtle (*Vinca minor*). This forms a great mass of long white roots, and long vines with abundant evergreen foliage, which resist stream wash by shingling the whole surface so that the water can scarcely reach the soil. Several other plants are under observation with reference to their possible utility as substitutes for blue-grass on ordinary lawns; in particular the attempt being made to develop varieties that are hardier than the lippias.

Among the most interesting of experiments thus far conducted are those having to do with the trailing species of hypericum from the mountains of eastern Chile. On the lawn in front of Mr. Burbank's dwelling at the present moment this plant has taken the place of the lippias. It makes a close mat of green, and it does not turn brown in winter. It grows somewhat less rapidly than the lippia, but there is good promise that selected varieties will make an excellent lawn cover.

Somewhat similar species of hypericum have recently been introduced by Mr. Burbank from Russia and from other parts of central and northern Europe. These show the same creeping habit, and no doubt will be hardy everywhere. Even the first generation from the wild native plants, these hypericums show a wonderful variation as to rapidity and compactness of growth. There is every reason to expect, then, that a few years of selective breeding, under Mr. Burbank's skillful supervision, will supply a lawn plant for all climates in many ways superior to anything hitherto known. Mr. Burbank makes this prediction with some confidence; adding, however, that the new plant may be a little more difficult to establish than ordinary lawn grass.

All the hypericums will stand a great amount of drought and ill treatment. Tramping does not injure them, and they may be moved like ordinary lawn grass. Observation of the varieties already under cultivation at Santa Rosa gives assurance that here is material from which a valuable new type of lawn cover will be developed. There is no reason why the amateur should not make experiments in selective breeding with the hypericums, even in localities where the more tender lippia cannot be grown.

ORDINARY LAWNS AND THEIR CARE

Until the lippias have been rendered hardy, however, or the hypericum or the other plants more fully developed, most residents of the northern climates must be content with the lawn grasses of the old familiar type, with the blue-grass at the head of the list.

Seeds for these grasses vary a good deal in quality, and Mr. Burbank urges that they shall be secured only of a reputable dealer. Pure blue-grass he thinks better for the ordinary lawn than any mixture.

The grasses themselves offer opportunity for great improvement through hybridizing and selective breeding, but the hybridizing of plants that have such small and inconspicuous flowers requires a good deal of skill. To such as wish to undertake it, however, it may be said that the process of cross-fertilization is in no wise different in principle from that employed in the case of other flowers. It will be necessary in many cases to work with a magnifying-glass, and delicacy of manipulation is essential. But if you have acquired skill through practice on the larger flowers of orchard and garden, the fertilizing of the grasses will offer no insuperable difficulties.

In particular, you may find interest in experimenting with some of the large ornamental grasses, such as pampas grass, which may readily be hybridized, and greatly developed as to size and artistic quality of the plume-like flower heads. Some of the pampas grasses bear the staminate and pistillate flowers in separate panicles, and hence may be cross-fertilized by merely dusting one flower cluster against another. At the time when the pampas grasses were more in vogue than they now are, Mr. Burbank developed many interesting varieties, using precisely the same methods of hybridization and selection that have been detailed in connection with the development of other plants.

Other grasses with which anyone may work, and which give promise of results of vast economic importance, are the familiar cereals, wheat, oats, and rye. Here fertilization is difficult, as the flowers are borne in closed receptacles; but, on the other hand, there is little danger of vitiation of the experiments through accidental crossing.

As an instance of what may be done, it may be noted that Professor Biffin, at Cambridge University, England, recently succeeded in developing a variety of wheat that promises to revolutionize the wheat-growing industry in England, by combining the strains of a hardy wheat of poor quality with a weak-stalked wheat having a good head. The experiment was carried out along Mendelian lines, and perfected in three generations, giving the farmers of England a wheat of good quality, immune to the rust that had devastated their fields.

Mr. Burbank has under way a series of experiments in which he has crossed all available varieties of wheat. In his experiment garden the present season one row of these hybrid wheats was found to have vitality that enabled it to stand up under drought and wind when all the companion rows (representing different combinations) had wilted.

It is easily within the range of the experiments of any amateur to conduct similar tests in crossbreeding and selection, starting with standard varieties of wheat or oats or rye, and working with an eye to the development of hardy and unusually productive varieties. It has been pointed out that anyone who would develop a race of wheat that would bear on the average one kernel more to the head would thereby add millions of

MR. BURBANK PLANTING CHOICE SEEDS

The seeds are being planted in a box or "flat" of the usual type. The work is being done in the room to the conservatory. Note the pile of prepared earth in the background, and the pots for transplanting seedlings that are to be given special attention.

bushels to the annual product, and thus confer a magnificent benefaction on the race.

Bear in mind that the experiments necessary for the development of new varieties of cereals may be made in a plot of ground a few feet square. There is no better use to which you could put one or two of the plots set aside on your lawn for ornamental plants. The cereal grasses are graceful plants, which, properly placed, would constitute a pleasing and novel feature of lawn decoration. And experiments with them might result in developments vastly surpassing in importance all other possibilities of your flower or vegetable garden.

It may fairly be assumed, however, that you are interested rather in the preparation of the soil for the lawn and in its care than in the improvement of the lawn grasses proper, inasmuch as these have already reached an advanced stage of development at the hands of numberless professional gardeners.

And as to this aspect of the matter, Mr. Burbank cites an experience of his own that is illuminative, and may well be narrated. It appears that when he first purchased the four-acre plot of ground at Santa Rosa that was afterwards to become so famous as the seat of his experimental labors, this land was wet and soggy of soil, and entirely unproductive. It had been the bottom of a pond at some remote period, and the soil retained an excess of moisture. Mr. Burbank's first move after purchasing the place was to drain it properly. This was accomplished by running a main line of four-inch tiles down the center of the tract with laterals of two-inch tiles joining it at right angles at intervals of forty feet. The laterals gather surplus water quickly after heavy rain, and the main pipe carries it to a small stream nearby. The slope of the pipes is one foot in forty feet.

THE WORLD'S MOST PRODUCTIVE ACRES

At first thought it seems rather surprising that two-inch pipes forty feet apart will adequately drain a moist soil. But Mr. Burbank points out that the drainage pipes are working day and night, with no rest on Sundays, and that they carry a great amount of water in the course of twenty-four hours. In point of fact, this system of two-inch laterals with a four-inch central pipe proved eminently satisfactory at Santa Rosa from the outset, and no change has been necessary in the thirty years it has been in operation. The pipes require no attention whatever,—they have never been even inspected since they were put down.

It is of course highly essential that each piece of tiling as originally laid should be perfect, and that the entire system should be carefully adjusted at the proper grade. The joints should be packed with clay. If any part of the line sags, sediment will collect and retard the flow of water.

By the mere installation of this simple system of pipes, the heavy adobe soil of Mr. Burbank's Santa Rosa place was made arable. The soil was then enriched by plowing in eighteen hundred loads of manure. Localized beds were subsequently modified to meet the needs of bulbous plants by mixing sand with the soil.

The net result of this treatment was to transform a tract that would scarcely support vegetation of any kind into the most productive four acres perhaps to be found anywhere in the temperate zone. Doubtless there is no other tract of similar size anywhere in the world that has produced so varied a crop of vegetation and such profusion of new and interesting and beautiful forms of plant life year after year as these transformed acres at Santa Rosa.

Mr. Burbank's experience affords a lesson by which everyone who has a small tract of land that he wishes to put in condition for lawn or garden may profit. Even if your land lies in a region where there is drought in summer, there are periods of the year when the ground is unduly saturated with water, and when it must be drained to permit the proper aëration of the roots of the plants. The drainage pipes will not take water from the soil except when there is an excess of it. For dry soil absorbs water sponge-like through capillarity.

So, unless your land is located on a hillside where there is the best possible opportunity for natural drainage, you will do well to install a system of drainage tiles like that described, and you may confidently expect that your lawn and garden will be noticeably benefited thereby.

As to the preparation of the soil itself, everything depends upon the local conditions, and only general rules can be given. If the soil is very sandy, it will be benefited by having clayey loam spread over it and incorporated with it by plowing. And there are very few soils that are so rich that they will not be benefited by thorough fertilizing. For this purpose barnyard manure has exceptional value, not only because it supplies plant foods, but also because it gives the right texture to the soil. Leaf mold from the woods, if it can be secured, has value for the same reason.

Nowadays it is well understood that the physical texture of the soil is almost as important as its chemical composition. The roots of the plants require air as well as water, and they will not thrive in a soil that lacks porosity. In the garden the soil is kept porous by constant cultivation, but this is obviously not possible with the lawn; hence it is especially important that soil for the lawn shall have the right texture before the grass seed is sown.

SUPPLYING WATER

The lawn that needs to be protected against an excess of water at one season by a system of drainage may at another season require artificial watering even more imperatively. The question of artificial irrigation is therefore no less important than that of artificial drainage.

Here again the needs of the lawn call for special consideration, both because the soil cannot be kept porous by cultivation and because the roots of the grass permeate the entire surface and exhaust the water supply very rapidly. The fault with most of the common sprinklers used to irrigate lawns and small gardens, says Mr. Burbank, is that they do not distribute the water evenly. Most of them cover a circular space, and there is always some part of the soil which has too much water while other parts have too little. One of the most important points in irrigation is to have the water distributed evenly.

Some of the flat or fishtail sprinklers distribute the water better than the older forms, but Mr. Burbank especially commends the newer system of overhead irrigation as far superior to the old forms of sprinkling. He recommends the use of a number of one-inch galvanized pipes with nozzles placed along the sides from twelve to twenty inches apart. The pipes, mounted on stakes at a convenient height, are connected with the water supply by ordinary rubber hose. A single system of pipes will water a space evenly to a distance of from twenty-five to fifty feet on either side. Thus an ordinary lawn may be supplied from a line of pipes at either side, and these pipes may be concealed by a trellis of ornamental vines.

The system may be so modified that the pipes instead of being held on permanent stakes are carried from one place to another and placed on temporary stakes or movable stands.

A modification of the system is to have the pipes underground, just at the surface. This has the advantage of having the pipes out of sight, but the system is more costly to install. The fact that the iron pipes last for many years should be taken into account, however. The part of the ordinary sprinkling system that deteriorates most rapidly is the rubber hose. The permanency of the iron pipe system soon compensates for the initial cost. Moreover, the saving in both time and water is notable, and the lawn is given a much more evenly distributed supply of moisture.

The same system may advantageously be utilized in the flower garden and vegetable garden. A single line of pipe may be arranged so that it will water the beds on either side. Where the prevailing winds come from one direction throughout the summer, it is advantageous to place the irrigating pipe on the windward side of the lawn or garden to gain the aid of the wind in spraying the water over a wider surface.

ORNAMENTAL FLOWER BEDS

There are few other lines of plant experiment to which Mr. Burbank has given greater attention than that having to do with the production of ornamental flowers adapted for massed display in beds on the lawn or in the dooryard.

He has introduced, for example, half a dozen new forms of callas, including varieties with spotted leaves that have a peculiarly striking massed effect; a dozen new dahlias of the most varied and beautiful forms and colors (among others, the first fully double ones, and a fragrant variety); more than twenty new gladioli of rare beauty; a large number of poppies of the most exquisite quality of petal and of rare colors; and numerous roses that reveal an unmistakable Burbank quality. Then, too, there are cannas, verbenas, larkspurs, myrtles, codetias, lobelias, pentstemons, eriophyllums, firecracker flowers, primroses, and the wonderful giant amaryllis, with a coterie of exotic forms of less familiar name, on the one hand, and perfected varieties of such familiar flowers as the milkweed and iris and petunia and bleeding-heart and goldenrod, on the other.

All of these have been brought under Mr. Burbank's tutorage, and have been made to reveal new possibilities of development of form or color or fragrance or profuseness of bearing. The experiment gardens at Santa Rosa and Sebastopol are objects of admiring attention to hundreds of visitors throughout the season, and the new forms of flowers here developed are sent out to gladden the hearts of flower lovers everywhere in the world.

However varied the qualities of the different flowers, the same general principles of development apply to all of them. Hybridization and selection are the keys to progress and plant development, whether we deal with gladiolus or with canna, with dahlia or with petunia, with mallow or with amaryllis. There are important details of difference, however, some of which will be outlined in a moment.

There is no reason why you should not improve upon any one of the flowers that ornament your lawn or dooryard. By applying your own taste in the selection of plants whose seeds shall be preserved, you may put the imprint of your own personality on new varieties, just as Mr. Burbank has put the imprint of his personality on the varieties that are now sent out from Santa Rosa.

Perhaps it may not have occurred to you, but it is nevertheless true, that the Burbank flowers have delicacy and artistic quality of form, and harmonious blending of color, and exquisite perfume because Mr. Burbank himself is a man of refined sensibilities to whom these qualities appeal. By the same token, you may develop, if you so elect, in the course of two or three seasons, new varieties of flowers that will represent your personality quite as fully as you are represented by your costume or the equipment of your boudoir. To have a flower garden of such unique individuality is surely a worthy ambition; and it is one that may readily be gratified.

IMPROVING THE GLADIOLUS

As illustrating the possibility of doing remarkable work with a very common plant, it is worth

A BURBANK HYBRID TIGRIDIA.

This is one of many interesting varieties of Hybrid Tigridia that Mr. Burbank has developed. The plants are spotted and not striped, yet there does seem to be something tiger-like about this richly caparisoned and oriental-seeming specimen. It is rather curious to reflect that the spots on the flower are intended to make it conspicuous, whereas the striped coat of its namesake is calculated to make the animal invisible in the jungle.

while to recall details already given as to Mr. Burbank's work with the gladiolus. He has worked with many varieties, and has raised the bulbs by hundreds of thousands; and there is scarcely a quality of bulb or stalk or flower that he has not modified in one direction or another.

The bulbs have been made to produce bulblets rapidly; they have been rendered hardy; and in particular they have been made relatively immune to disease. The stalks have been caused to grow to gigantic size, and to bear flowers not merely on one side, as they were formerly wont to do, but in spirals that showed the flowers in a solid cluster, the blossoms facing in all directions. The flowers themselves have been very markedly increased in size, and given brilliancy of coloration and remarkable keeping quality.

Mr. Burbank says that the possibilities in experimenting with color in the gladiolus rival the experiments that a painter makes with the pigments of his palette. Mr. Burbank himself has a remarkable color sense, and he takes particular delight in modifying the shades of color of his flower creations, and enhancing their delicacy and beauty. He has found that certain combinations of colors can be made, quite as in the case of the artist's pigments, with pleasing results, and that other combinations should be avoided. If a pink gladiolus, for example, is combined with a white one, the result will probably be a paler pink that is not pleasing. On the other hand, it was by combining a small purplish gladiolus, imported from Europe, with a white one that Mr. Burbank produced his remarkable blue gladiolus. Flower lovers are aware that the gladiolus, like the poppy and rose, is not partial to the color blue. Yet Mr. Burbank has succeeded, after a long term of experimentation, in developing a blue strain of gladiolus that is as beautiful as it is unusual.

Mention has been made of the white gladiolus, but it should be explained that this flower is not pure white, as comparison with a white watsonia flower will show. The white of the watsonia has been termed "the whitest white in nature." It is of interest to recall that the progenitor of the white watsonia was a "sport" found in the native home of the plant, South Africa, in a region where watsonias of the normal reddish color were abundant. The white sport bred true, and it was presently introduced in the gardens of Europe and America.

Unfortunately, the watsonia is a rather tender plant, and this has interfered with its popularity in the eastern United States. Yet it is a plant worthy of cultivation, and one that in many ways rivals the gladiolus, which it somewhat resembles. It has been a favorite flower with Mr. Burbank, who, besides improving it in many features of bulb and stalk, has devoted particular attention to the development of its color possibilities. By combining the white and red strains, and making various recombinations of the offspring through many generations, and by rigid selection among the flowers showing slight variation, he has developed watsonias of multiform colors, some of which show delicate shades of purple and pink that are rivaled only by the orchids.

THE ROTATION OF CROPS

In his work with the bulbous plants, Mr. Burbank has met with peculiar difficulties because from time to time his fields have been invaded by a pestiferous little mammal, the pocket gopher, which burrows underground, and which has on occasion destroyed thousands of his choicest bulbs before the presence of the marauder was detected. At one time the gophers became so destructive—seeming always, as Mr. Burbank says, to select his choicest bulbs—that the plant breeder was led to give up the cultivation of the gladiolus and of various allied bulbous plants. Only after almost numberless experiments did he find a method of coping with the rodents.

The successful device was a kind of gun that is exploded just at the moment when the body of the gopher is in contact with a quantity of powder. After this device was in hand, Mr. Burbank returned to the interrupted line of experiments with the bulbs, and his experiments with plants of this character have been among his most important works of recent years.

In carrying out these experiments on an extensive scale, he has discovered that there are other pests that are almost as destructive as the gopher. The bulbous plants, indeed, are peculiarly subject to the attacks of various fungous and insect foes. It is in the endeavor to ward off these foes that most bulbs have developed a bitter principle. In many cases, however, the insects refuse to be discouraged by the bitter taste, and eat the bulbs with avidity, often working destruction to the choicest specimens, and making progress impossible.

To guard against such mishaps, Mr. Burbank recommends that any soil in which bulbous plants are grown should, if possible, be thoroughly sterilized before the bulbs are set out. Where the quantity is small, it may be possible to dig up the soil and sterilize it by baking. When this is impossible, something may be accomplished by the use of germicides. In recent years Mr. Burbank has used large quantities of a liquid preparation known as tuolene, and he regards this as the best germicide that he has ever used.

By impregnating the soil with this solution, protection is given the delicate bulbous plants, and they may thrive where, if not given such aid, they would inevitably have perished.

It is impossible, however, to rid the soil permanently of all fungous and insect intruders. Where bulbs are grown in the same soil, in successive seasons, these enemies are sure to accumulate. Moreover, the roots of plants may give out excretions that render the soil noxious for that particular species. Therefore, Mr. Burbank especially recommends that anyone having to do with bulbous plants should change the location year by year, never having the same bulbs in a bed two years in succession. It is better, indeed, not to raise plants of any one kind for successive seasons in a bed, but to alternate between bulbous plants and annuals grown from the seed. Failure to carry out such a rotation of crops is a very common source of failure with the amateur gardener. It is not at all unusual to see an amateur obtain excellent results for one or two seasons, and then to have her garden degenerate simply because she has attempted to raise the same kind of plant year after year in the same location. By transposing the different plants—putting the gladioli this year where petunias, for example, were grown last year, and the like—all the plants may be kept in vigorous growth. Attention to this detail may make all the difference between success and failure in the disposition of flower beds to ornament the dooryard.

If it is your desire to keep bulbous plants year after year in the same bed, you may accomplish this if you are willing to take the trouble to dig out the top soil and pile it up in some out-of-the-way corner and replace it with other soil, which will in turn be dug up and piled for renovation next season. After lying in a heap exposed to air and sun for a season, the dirt becomes thoroughly sterilized, and may be restored for use the ensuing year.

In other words, you may have two coats of soil for your flower bed, to use in alternate seasons.

Mr. Burbank does not employ this method, as he works on too comprehensive a scale, but it is used by Professor Hugo De Vries, the celebrated Amsterdam botanist. In his experiment gardens at Amsterdam, you may see heaps of dirt being thus renovated with the aid of time and the elements, and any amateur who operates on a small scale may imitate the example.

Ordinarily, of course, it will be more expedient to practice rotation of crops, giving your soil the additional benefit of occasional sprinkling with a germicide. But for the benefit of the small beds located in some particular part of the lawn where you wish, for example, to keep cannas or gladioli or tulips season after season, the more troublesome but highly effective method of using two coatings of soil in alternate years may be worthy of consideration.

SOME GIGANTIC FLOWERS

Among Mr. Burbank's almost endless experiments with bulbous plants, perhaps none have greater interest than those that have to do with the not very familiar plants which are known to the horticulturist under the name of Amaryllis, but which really belong to several somewhat closely allied genera. One true amaryllis (the so-called belladonna lily) is a rather common plant indigenous to the United States. But the plants that go by the name in horticultural circles are mostly of the genus *Hippeastrum,* and have been brought to us from the tropics. There are also the allied genera of *Crinum* and *Sprekelia.*

Mr. Burbank has hybridized these plants in a great number of combinations, and has produced some very striking and remarkable results.

His work with the plants of the genus *Hippeastrum*—making up the body of the flowers usually termed amaryllis—has had to do with a number of species that have been long under cultivation, including some that have been earlier hybridized, as well as with less familiar species imported from tropical regions.

At first Mr. Burbank had difficulty in hybridizing these plants, but he presently discovered that the difficulty lay solely in the selection of just the right time to apply the pollen. The pistil does not become mature until after the pollen of the same flower has been discharged. By bearing this in mind, and gathering pollen on a watch crystal, if necessary, to await the maturing of the pistil of another flower, cross-fertilization presents no difficulties. By working for twelve or fifteen successive seasons, Mr. Burbank produced complex hybrids that are really very remarkable plants. Some of them have enormous bulbs, with a propensity to produce bulblets at a really astonishing rate.

Many varieties of amaryllis produce only one or two bulbs in a season, which accounts for the fact that these bulbs are costly. But Mr. Burbank so stimulated the bulb-producing capacity of his hybrid varieties that his most prolific species will produce a new bulb every week, or fifty new bulbs in a year.

In point of prolific bearing, there was corresponding progress. Not only do the hybrid species produce large stalks, but they produce four or five stalks to a bulb, instead of the original two or three, and sometimes as many as twelve flowers to the stem (when they have remained in the ground for a few seasons), instead of the original four or five flowers in a cluster. The enhanced fecundity of the new forms is supplemented by their tendency to early bearing. They will sometimes bloom the second year from seed, and on the average they bloom in three or four years; whereas the old forms sometimes required six or eight years to come to maturity. Thus Mr. Burbank has pretty nearly cut in half the time from seed to blossom in the amaryllis. Hybridization and selective breeding are of course the magic methods that accomplish these results.

But the most spectacular transformation has to do with the flowers themselves. In the original species, the largest flower seldom attained a diameter of more than five or six inches. Mr. Burbank's hybrid species of giant amaryllis produce flowers that are almost a foot in diameter.

These megaphone-like flowers of the giant amaryllis are among the most striking, as well as among the most beautiful, objects to be seen in Mr. Burbank's experiment gardens.

It should be added that the giant amaryllis does not produce its largest flowers until it has at-

A VIEW OF MR. BURBANK'S GARDEN AT SEBASTOPOL

The central rows are selected specimens of the calla. Scores of other choice varieties of plants fall within the range of the camera. Note the straightness of the rows and the general evidence of thrifty gardening.

tained full maturity. The flowers may increase in size for several successive seasons as the bulb gains size and strength.

Moreover, it is necessary to give the bulbs good treatment—rich soil, plenty of water and sunlight —in order to have them reveal their full possibilities. In particular, Mr. Burbank points out that a bulb that has been ill-treated in its first season will never produce a large flower, even though it have the hereditary factors for large blooming.

The amount of patient work required to secure just the right combinations will be appreciated when it is said that Mr. Burbank experimented for about fourteen years before obtaining varieties of amaryllis that seemed worthy of introduction.

I had an illustration of the precocity of some of these plants when an amaryllis bulb brought from Santa Rosa and potted indoors in New York in the month of April sent up a flower stalk and put forth the first of a series of beautiful blossoms in the extraordinary short space of eight days.

ENORMOUS BULBS OF HYBRID CRINUM AND AMARYLLIS

Mr. Burbank has crossed the true amaryllis with plants of the genus *Crinum* with spectacular results.

Some of the hybrids have enormous bulbs,—

far larger than a man's head,—and their flowers seem intermediate in character between those of the parents. But the two plants are evidently pretty nearly at the limits of affinity, and while the hybrids put forth flowers abundantly, they do not have viable seeds.

Of course the new plants may be propagated indefinitely from bulbs, so that the hybrid crinums constitute interesting permanent varieties. But the experiment cannot be carried beyond the first generation because the hybrids are sterile. Such, at least, has been Mr. Burbank's experience. It is quite possible, however, that it may be feasible to find species of crinums or individual flowers that would produce fertile offspring when crossed with the amaryllis. At least further experimentation along this line is worth making.

It would also be of interest to attempt to cross the crinums with the hippeastrum or tropical amaryllis, a combination that Mr. Burbank has attempted many times, but hitherto without success.

All in all, the plants of the amaryllis tribe furnish rare opportunities for experiment in the hands of the amateur, particularly since Mr. Burbank has developed species that are sufficiently hardy to thrive out of doors in our northern latitudes. A good deal of patience is required, to be sure, in awaiting the maturation of the flowers; but experiments in cross-pollenation may be begun without delay, if you start with mature bulbs. The pollenizing of the flowers presents no difficulties whatever, if care is taken to apply the pollen to the pistil when it is fully mature.

To make sure of this it is well to apply the pollen on several successive days. With some species the maturing of the pistil is marked by its curving upward; in others it elongates rapidly, the result in either case being to place the pistil where it will be likely to receive pollen from the large moths or the humming-birds that ordinarily fertilize tubular blossoms of this type.

WORKING WITH THE RESPONSIVE DAHLIA

Apropos of the pollenizing, it may be well to call attention to difficulties that confront the worker when he deals with the composite flowers, of which the various sunflowers and the dahlia furnish familiar examples. The peculiarity of the composite flower, it will be recalled, is that a large number of blossoms are gathered in a single head, about which a conspicuous circle of ray flowers or florets is displayed.

This is an example of communism in the plant world, as a single circle of petal-like appendages is made to serve as an advertisement to insects for all the numerous blossoms of the cluster, whereas ordinary flowers have a set of petals for each individual blossom. But whereas this arrangement is eminently satisfactory from the standpoint of the plant itself, the grouping of flowers in a mass obviously complicates the problem of the hand pollenizer.

The best practical method in cross-pollenizing composite flowers—for example, dahlias—is to wash away with a spray of water the pollen of the flower head that is to be fertilized, afterwards rubbing its surface gently with the pollenizing head plucked from another plant. Of course you cannot always be sure that the flowers have not been fertilized by pollen from other florets in the same head before you began operations. Moreover, as the flowers of the head do not mature all at the same time, but gradually ripen from circumference to center, you must repeat the operation on several successive days to make sure of hybridizing a large proportion of the blossoms in a given head.

At best there will be an element of uncertainty about the result, but this will give additional zest to the experiment and increase the interest with which you will await the blossoming next season of the plants grown from the seeds of a flower head thus manipulated.

The dahlia furnishes perhaps the best example of a familiar composite flower with which you may begin your experiments in this somewhat more difficult type of cross-pollenizing. As these flowers are at their best late in the fall, there is still abundant opportunity for work during the present season. And notwithstanding the large amount of work that has been done with the dahlia, you may hope to secure very interesting new developments.

Mr. Burbank has worked very extensively with this group of flowers, and has produced some very striking hybrids by combining the familiar garden species with wild species brought from Mexico. You may secure a sufficient variety of dahlias from any florist to give ample opportunity for further hybridizing experiments. No dooryard would be complete in its autumnal floral display that did not have a bed or two of these very attractive flowers.

The wild progenitors of the modern races of dahlias have flowers with a single row of florets, like the wild sunflowers. The complex rounded heads of many cultivated varieties are due to the transformation of the minute and originally inconspicuous florets of the cluster under the stimulative influences of changed environment and artificial cultivation.

To observe the contrast between the wild dahlia and its cultivated descendant is to receive a vivid object lesson in the possibilities of flower development.

Even without hybridizing, you may develop a great variety of dahlias. All the varieties under cultivation are complex in their heritage, and the fact that the plants may be multiplied by division has made it unnecessary to carry selective breeding to the stage of fixing qualities so that plants grown from the seed will reproduce in detail the features of their parent plants.

You may find endless amusement and interest in selecting new varieties from among the plants grown from a single packet of seeds, and you may try your hand at fixing new types by careful inbreeding and further selection. A very interesting experiment may be made by planting all the seeds from a single dahlia head in separate plots; carefully screening each plant against cross-pollenation, and noting results in the second filial generation. Each seed may seem to give a unique variety, and by persistent selection through several generations, following the same method, you may secure an endless variety of interesting types. Meantime, any individual that you prize may serve as the progenitor, through root division, of an entire race exactly like itself.

STUDIES IN COLOR VARIATION

The dahlia also offers large possibilities for the study of color variation, and for experiment in the blending of different colors to produce new types. As illustrating the possibilities of development of this flower, it may be recalled that this is one of the most recent acquisitions in the flower garden, the dahlia having been brought under cultivation only four or five human generations ago.

The species of dahlia first introduced from Mexico was brought to England in the year 1789 by the Marchioness of Butte. It had the general form of a very large daisy, and it resembled numerous familiar wild sunflower-like composites, except that its floral envelope was dull scarlet with a yellow center. Subsequently other species were introduced, and through hybridization and selection the flower was not only made to take on the greatly modified form with which we are familiar, but its color scheme was indefinitely modified, although the original red and yellow, together with the white and crimson of certain other species, form the basis of coloration of all the cultivated varieties. Almost any of these show sufficient diversity of color to make interesting experiments in blending and modifying their color scheme feasible.

Equally interesting studies of color variation may be made with the different types of roses. Added zest is given to these experiments by the fact that many of the roses are not readily cross-fertilized. Mr. Burbank tells us, for example, that he has grown upward of two hundred thousand seedlings from the crimson rambler pollenated with all the ordinary roses that are under cultivation in California. He found that the pollen of only a few roses proved effective. Here and there a rose like the Empress of India or the Cecil Bruner would pollenize readily with the rambler, and the hybrid progeny would sometimes cross readily with numerous other hybridized roses with which the crimson rambler itself could be united with difficulty, or not at all. Under these conditions, it is obvious that the hybrids soon become very complex as to their ancestry, and the sorting out and isolation of their hereditary factors in new combinations may become a fascinating puzzle.

Still another familiar flower with which work in color variation may readily be carried out is the verbena. "The ancestors of the cultivated verbena were South American plants, and it is believed that there are four chief species that have been variously hybridized to produce all the forms now under cultivation. One of the original species bears flowers of brilliant red, two others have flowers that are rosy or purple in color, and the flowers of the fourth are pure white."

The hybridized races show the breaking up of these colors, quite as might be expected, with a presentation of all the primary colors in many of their hues and gradations, although pure blues are not well represented, and pure yellow is very exceptional. To experiment in the production of new colors and combination of colors, it is not necessary to hybridize the verbenas, as few if any of the familiar forms breed true from the seed. "You may secure all the variation that is desirable among the plants grown from a single packet of seeds, and may isolate and fix by selection an indefinite number of new types with color schemes that please your eye. It is possible, also, that you may find among your verbenas an exceptional flower with a pleasing odor, and this also may serve as the basis for an interesting series of experiments in selective breeding. Through such an accidental discovery, Mr. Burbank was able to develop two varieties of fragrant verbenas which were introduced under the names of the Mayflower and the Elegance.

" In each case the plant from which the fragrant

BEDS OF SHASTA DAISIES

The picture illustrates the admirable quality of the Burbank Shasta daisy as a border flower. The plant is notable as being the hybrid descendant of three different species of daisies, indigenous respectively to Europe, America, and Japan.

race was developed was found among thousands of companion seedlings, most of which, as is usual with the cultivated varieties, had a rather disagreeable odor. A large number of races of fragrant verbenas have been developed from the two that Mr. Burbank isolated in his garden.

"The explanation of the appearance now and then of a verbena with a pleasing odor is found in the fact that one of the original wild species the strains of which have been blended to produce the cultivated varieties has a rich jasmine fragrance. The early cultivators, giving heed to the color and form of their hybrid plants, ignored the matter of fragrance, so the verbena developed wonderfully symmetrical clusters, and its flowers took on the most gaudy hues, but these handsome blossoms were of rather disagreeable odor until the submerged quality of fragrance was brought out—the coveted qualities of form and color being retained—by selective line breeding."

ORNAMENTAL SHRUBS AND VINES

It is not necessary to speak in detail of the other familiar border and bed flowers—salvias, petunias, geraniums, roses, and the rest—that are everywhere available for the ornamentation of lawn and dooryard. The selection and distribution of these are matters of individual taste. There is no one of them that does not offer opportunities for interesting experiments and improvement, but the details of these experiments are readily mastered by anyone who has grasped the fundamental ideas of plant development through hybridization and selection. A few words must be added, however, about the shrubs and vines that break up the long stretches and furnish an essential border or background of foliage on the walls or trellises or pergolas about your lawn. No dooryard is quite complete without such a background.

Needless to say, Mr. Burbank has not overlooked this esthetic requirement. Among the shrubs and small trees of more familiar type with which he has worked extensively in producing materials for hedge or lawn decoration are the black alder, the barberry, the flowering dogwood, the sumac, the elder, the hazelnut, the mulberry, the osage orange, the laurel, the rhododendron, the witchhazel, the wild plum, and the abutilon or flowering maple from Chile.

All these have attractive qualities of foliage, and a good many of them have added attractiveness because of their beautiful flowers or their edible fruits. Almost all of them give opportunity for experiments in development by crossbreeding and selection, that add to their attractiveness from the present standpoint. If you have none of them on your grounds, it will be well to secure a few for transplantation this autumn, to be ready for hybridizing experiments next season.

With the ornamental vines, Mr. Burbank has worked no less extensively, and he has developed these in sufficient variety and profusion to meet every need. The ivies, for example, have been given a vast deal of attention, in particular the members of the genus *Ampelopsis,* of which the Japanese ivy and the Virginia creeper are perhaps the best known. One of his new varieties of Virginia creeper is an extremely rapid grower, and has the habit of holding its foliage until a late period in the autumn.

Mr. Burbank has been unable to hybridize the Japanese ivy and the Virginia creeper, but he says that he sees no reason why the two should not be crossed, and he believes that if the combination could be made, it would result in the production of new vines of almost priceless value. The number of ornamental vines is comparatively limited, and an addition to the list would be welcomed. Here, then, is a field in which the amateur may advantageously work. You may readily grow both the Japanese ivy and the Virginia creeper, and the attempt to hybridize them would have added interest because of the uncertainty of the result.

A vine with which Mr. Burbank has attained exceptional success is the beautiful clematis. This vine not only rivals the ivies in its capacity to clamber over walls and arbors, but it has the added merit of producing remarkable flowers. Even the native wild species produce attractive blossoms, and the hybrid species that Mr. Burbank has developed have a variety of flowers of extraordinary interest and beauty.

The familiar wild form has single star-like flowers of comparatively small size. The hybrid varieties, produced by blending the strains of eight or ten species, show an extraordinary range of variation both as to form and color of flower. The petals of some varieties have a singular frosted appearance. Some of them are bell-shaped, others have petals that are fluted and feathery, bearing a curious resemblance to ostrich plumes.

Unfortunately some of the new varieties of clematis are somewhat lacking in hardiness. There are several wild species, however, that grow in the regions of northern Canada where the mercury goes fifty or sixty degrees below zero. It is certain that further hybridizing experiments in which these hardy species were utilized would result in giving new varieties that would combine the qualities of flower of Mr. Burbank's beautiful clematis with the hardiness of the northern race.

Other ornamental vines with which Mr. Burbank has worked extensively are the bignonia, the wistaria, and the bellflower. He points out that a good deal of work remains to be done by crossing the hardy bignonias with the tender ones, there being excellent prospect that new varieties of value will thus be produced. The wistarias, also, he says, offer interesting possibilities. They are difficult to pollenize because their flowers are papilionaceous, like those of the peas and beans. But anyone who has experimented with the latter will have no difficulty with the wistarias. Mr. Burbank suggests that some very striking variations should be obtained in the second generation from a cross between the American and the Chinese species.

The Chilean bellflower is another ornamental vine that bears beautiful flowers. Mr. Burbank regards this as among the most beautiful of all blossoms. He describes it as a glorious, great drooping bell-shaped rosy or white blossom, which no lover of flowers could fail to admire. Unfortunately the plants are very difficult to raise, needing peculiar soil and much attention. They are also sensitive to changes of temperature, and they must be kept moist at all times. Mr. Burbank has experiments under way in which the attempt will be made to hybridize this plant with other forms, in the hope of securing a new ornamental vine that will be adapted to our northern climate.

Meantime the amateur will perhaps do well to begin his experiments with the hardier material supplied by the ivies, clematis, and wistaria. These, however, give ample opportunity for the exercise of ingenuity, and full promise of interesting developments.

CHAPTER X

BURBANK'S WAY WITH TREES

OF the many extraordinary things observed when I first visited Mr. Burbank, perhaps nothing impressed me more than the experience at Sebastopol, when the plant developer, with eyes a-twinkle, invited me to "stoop down and pick some chestnuts from the top of yonder tree."

The invitation was one that could be accepted in a literal sense; for we were standing in the midst of what might be termed a chestnut forest in miniature. About us were "trees" heavily laden with chestnut burs inclosing nuts of the very largest size; and the tops of said trees were some of them only knee-high, others being as high as the waist. One had literally to stoop if one wished to touch the tops of many of these anomalous nut-bearers.

Yet the burs with which these miniature trees were laden were obviously chestnut burs, the leaves of the trees were those of the chestnut, and the nuts themselves were found, on testing, to be chestnuts not only of extraordinary size but of the finest quality.

To one who is accustomed to gather chestnuts on occasion that have fallen from branches scores of feet in the air, it seemed a culminating paradox to find larger chestnuts than the mammoth trees of the East ever produce growing on tiny bushes. White blackberries and thornless briers, stoneless plums and seedless grapes, cactus slabs without spines, perfumed callas, blue poppies,—I am not sure that any of these seem quite so paradoxical as the dwarfed chestnut tree with its load of mammoth nuts.

It goes without saying that the anomalous chestnuts have an interesting history. Although they are still undergoing training in the plant school at Sebastopol, they are nevertheless among the most ancient of Mr. Burbank's remarkable plant productions. The experiments that led to their production were begun as long ago as the year 1884. In the autumn of that year Mr. Burbank received his first shipment of plant products from Japan. Among the varied things thus imported from the Orient, few had more interesting possibilities than the packet that was labeled in a memorandum: "Twenty-five monster chestnuts."

Some years earlier, while Mr. Burbank was still a young man in the East, he had observed that the American chestnut varies rather strikingly, some trees producing much finer nuts than others; and had noted this variability as seeming to offer opportunities for selective breeding. Now it occurred to him that the Japanese chestnuts gave material for hybridizing experiments through which the natural tendency to variation might be accentuated. That remarkable results would thereby be attained the plant developer had no doubt. Just what these results would be, it remained for the sequel to determine.

HOW THE PRECOCIOUS DWARFS WERE MADE

There were already at hand at Santa Rosa specimens of the ordinary American chestnut of the Northeast and of the somewhat closely related European chestnut, as well as of the small allied species of our southeastern states, known as the chinquapin. Mr. Burbank at once set about blending the strains of these three species with the strains of the newcomer from the Orient. Each species was crossed with all the others, that the results of different combinations might be tested.

Of course the hybrid of the first filial generation blends the strains of only two species. But it is equally obvious that if these hybrids are themselves interbred, the strains of four species may be combined in the complex hybrid of the second filial generation. For example, the hybrid progeny of the Japanese chestnut and the chinquapin crossed with the hybrid progeny of the European and American chestnuts will produce offspring in which the strains of the four species are evenly blended. It is not to be expected, of course, that this hybrid will combine the desirable qualities of the parents in just the right proportion. But some of the desirable qualities will be

QUANTITY PRODUCTION APPLIED TO THE WATSONIA

The Watsonia is a South African plant with which Mr. Burbank has experimented extensively. From such a bed as this, a few choice specimens will be selected for preservation and the remainder destroyed. Eight cords of bulbs of the Watsonia have been destroyed at one time, in this garden at Sebastopol.

shown by a few at least of the progeny having this complex heritage.

Suppose, for the sake of illustration, that one of these second-generation hybrids is exceedingly productive and bears a nut of fine quality but lacking in size. The next step of the experiment, then, would be to hybridize this individual with the Japanese chestnut, one of its grandparents, which bears very large nuts.

The offspring of this cross will probably have some representatives that combine the exceptional qualities of one of their parents with the large size of the other.

A moment's reflection will make it clear that where four species are in question it is possible to unite their strains in an almost endless number of combinations in successive generations. This was precisely what Mr. Burbank did in the case of chestnuts from three continents. He blended their strains this way and that, noting results, and being guided thereby in making new tests; until presently he had quite the most remarkable chestnut trees that had ever been seen, including, among others, the dwarfed forms to which reference has already been made.

But how, it will naturally be asked, could experiments of this intricate character be carried out in one man's lifetime, when we are dealing with a tree that ordinarily does not begin to bear fruit until it is several years old?

The answer gives us an insight into another very remarkable feature of the experiment. "It appears that the chestnuts with which Mr. Burbank was experimenting carried submerged in their germ-plasm the possibilities of very precocious bearing. Always on the alert to observe variation in this direction, Mr. Burbank selected eagerly among the hybrid seedlings even of the first generation for those that showed a propensity to rapid growth and early development.

" By breeding only from these more precocious plants, he had presently developed races of hybrid chestnuts that would blossom and fruit in their second year, if their stalks were cut and grafted on branches of older trees.

" Continuing the experiment, he finally developed plants so extraordinarily precocious as to bear large, fully matured nuts on the tiny stalk, growing on its own roots, in its first season. Within six months of the time when a chestnut was planted, the plant that sprang from that seed might bear its two or three burs of chestnuts, thus rivaling the familiar annual plants in its precocity of development, and seeming to bid defiance to the hereditary traditions of nut-bearing trees.

" In their succeeding years these precocious chestnuts attain the size of bushes, but they have lost utterly the capacity to grow to tree-like dimensions. In leaf and fruit they are unmistakably chestnuts, but in manner of growth they have departed absolutely from the recognized traditions of their family. "

It should be explained, perhaps, that the ancestors of these precocious dwarfs were selected from among thousands of hybrid seedlings. Among the thousands, there were of course representatives of numberless different combinations of the ancestral traits of the four parent species. It would have been possible to develop gigantic races as well as dwarfed ones. Some of the specimens first developed were of large size and enormously prolific. But to Mr. Burbank it seemed that the most desirable type of chestnut for the purposes of the horticulturist would be one that produced an abundant crop of exceedingly large nuts on a tree that attained only shrub-like proportions. So his selections were made with this idea in mind, and the dwarfed chestnuts of Sebastopol are the tangible exemplification of that ideal.

In conducting his experiments, of course Mr. Burbank, here as always, had in mind a great variety of desirable qualities. One of his novelties is a line of hybrid chestnuts in which the burs are being deprived of their spines through selective breeding.

It has been pointed out that he seeks always to develop plants that show great resistance to disease. The hybrid chestnuts are no exception to the rule. There is reason to believe that they are immune to the attacks of the fungous pest that has destroyed the native chestnuts everywhere in the neighborhood of New York, and which is extending its ravages in all directions year by year, with full prospect that ultimately it will leave no tree of this species standing between Maine and the Carolinas.

The destruction of our native chestnuts has been justly regarded as a calamity. It is a consolation to know that the hybrid chestnut will probably be available to restock the devastated regions with a tree that will more than compensate for the loss of the native chestnut as a producer of nuts.

Doubtless it will be possible also to produce hybrid strains that will combine immunity to the pest with capacity for lumber production, at least equal to that of our native tree, and perhaps vastly superior.

THE PRODUCTION OF GIANTS

The warrant for the latter supposition is found in a line of experiments conducted by Mr. Burbank with another tribe of nut-bearers; namely, the walnuts. His success in producing extraordinary giants of this tribe was no less striking, and in some respects even more important, than his feat of producing the dwarfed chestnuts. The story of this accomplishment must be told in detail, as it furnishes an insight into what ultimately may prove the most important, from an economic standpoint, of all Mr. Burbank's discoveries.

The initial experiments in this case also were made many years ago, so that successive generations of the remarkable trees in question are in evidence. These trees are of two distinct tribes. One of them originated through hybridizing the indigenous California black walnut with the Persian walnut (commonly called English walnut), the other through hybridizing the California black walnut with the black walnut of the eastern United States, which is a distinct species.

The cross between the two species of black walnut resulted in the production of a tree that grew with extraordinary rapidity, and that ultimately proved an enormously prolific bearer of nuts. This hybrid tree was given the name of the Royal walnut. It differed somewhat in appearance from either of its parents, but its most striking peculiarity was its amazing capacity for growth and its no less amazing fecundity. The individual nuts that it bore were considerably larger than those of either parent, and the crop was multiplied many fold.

Long before the Royal hybrid had come to the age of bearing, however, Mr. Burbank had made the successful experiment of crossing the California black walnut with the Persian walnut. This was a far more remarkable cross, because the species are much less closely related, one of them being indigenous to the eastern hemisphere, the other a native of California.

The hybrid offspring of these widely different trees showed such striking peculiarities that it was named the Paradox walnut.

Like the Royal hybrid just referred to, the Paradox showed an extraordinary capacity for growth. It sprang up and increased month by month and year by year at a rate altogether unsuggestive of the characteristics of either parent. When nine years old trees of this mixed heritage towered far above the parent Persian walnut, still standing just across the way, and then in its twenty-ninth year. The foliage of the Paradox hybrid resembles in form of leaf that of the Persian walnut on a magnified scale; but the individual leaves are much more numerous on the leaf stalk, showing the influence of the California parent. The bark of the tree is light in color, not dissimilar to that of its European progenitor.

For a number of years the Paradox was supposed to be altogether sterile, and although in subsequent years it produced a few nuts which proved to be viable, it never bore more than a very small fraction of the crop that was habitual with its Royal cousin. Seemingly the hereditary gap between the parents was so wide as to carry it almost to the limits of affinity; whereas the relationship between the two species of black walnut was precisely such as to insure enhanced fecundity.

Yet in point of individual vigor the Paradox competes on an even footing with the other tree. Indeed, these trees vie with each other, and defy the competition of all other trees in their rapidity of growth, and in the gigantic stature that they attain at a relatively early age. There are several individual specimens of these interesting hybrids at Santa Rosa and Sebastopol that are now more than twenty years old. To anyone familiar with the habit of growth of uncrossed walnuts, who observed them without knowing their origin, it would appear that they must be at least three-quarters of a century old.

Notwithstanding the extraordinarily rapid growth of these trees, however, it was found that the wood they produce is of the hardest texture, capable of taking on an excellent cabinet finish. Most trees that grow with relative rapidity produce soft wood, but these hybrid walnuts are notable exceptions to the rule. The timber they produce is in no wise inferior to that of the parent black walnut; and this wood, as is well known, was so famous for its quality that the trees producing it were almost exterminated in the United States.

Here, then, are revealed new possibilities of the production, through hybridization, of timber trees of unrivaled capacity for growth.

The possibility of restocking deforested regions with trees of such rapid growth is very alluring. The most disheartening feature of the entire problem of reforestation has been the fact that trees that make good timber are so universally observed to be of slow growth. An oak fifty years old is a tree of relatively insignificant size; another half-century is required to make it a tree of commendable proportions. Even the relatively quick-growing chestnut and elm are three-quarters of a century old before they assume proportions that could be called imposing.

But hybridization so stimulates the vigor of the walnut that it sometimes grows ten times as fast as either of its parents. Some of Mr. Burbank's trees increase by a full inch in diameter in a single year. At ten years from seed, these hybrids are beginning to assume proportions that make them have value in the eyes of the lumberman. At twenty years they are handsomely proportioned trees of notable dimensions.

The contrast between a Paradox or a Royal walnut and a black walnut or a Persian walnut of the same age, at any stage of growth, is startling.

If we attempt to explain these anomalies of growth, we must assume that the remote ancestors of the walnuts—away back, let us say, in the preglacial days—were trees of gigantic size. Their descendants of our day are a relatively degenerate lot, made so by the modified climate to which they have been obliged to adapt themselves. But the mingling of germ-plasms of the different species makes it possible, in some way that we as yet do not very clearly understand, for the hereditary factors of giganticism, long submerged, to make their influence felt.

A somewhat similar stimulus to vigor of growth is a not unusual attribute of hybrids. We have seen that many of the large fruits and flowers and vegetables that Mr. Burbank has produced are thus to be explained. But the case of the walnuts is so extreme that these trees stand in a class by themselves. It is doubly significant because these are the first experiments in hybridizing forest trees that produced notable results; and because, as I said, the ultimate economic importance of this discovery can scarcely be overestimated.

There is apparently no reason why the same principle of hybridization should not be extended

A NEW BURBANK ROSE

Mr. Burbank has experimented very extensively with roses, producing many new varieties, one of which took the gold medal at the St. Louis exposition. The specimen here shown was selected almost at random from among hundreds that were equally attractive.

to other forest trees, giving us oaks and maples and hickories of rapid growth, to repopulate the hillsides and valleys of our eastern states made barren through the cupidity and lack of foresight of our ancestors.

SECOND-GENERATION HYBRIDS

In point of fact, nature herself occasionally points the way by making a demonstration of the value of hybridization in the case of forest trees, quite along Burbankian lines, as we shall see presently. But for the moment I wish to trace a little farther the history of the hybrid walnuts, for these show interesting developments in the second generation that are full of significance.

Second-generation hybrids of the Royal walnuts were readily enough secured, since this tree, as we have seen, proved enormously prolific. The value of the new tree, particularly to furnish roots on which to graft scions of the Persian walnut, was early recognized, and Mr. Burbank sold in one season more than a thousand dollars' worth, from a single hybrid tree to be used for seed purposes. The Paradox walnut, on the other hand, produced so very scant a harvest that it could be multiplied but slowly. Such nuts as they did produce, however, proved to be viable.

But the seedlings that grew from nuts of both Royal and Paradox walnuts proved to be a most variable company. Some of them showed capacity for growth fully equaling that of their hybrid parents; but others were extraordinarily dwarfed, growing far less rapidly than ordinary walnuts. Plants side by side, grown from nuts picked from the same stem, might differ so radically that they would seem to belong to totally unrelated species. One seedling might grow ten inches in height, while the one beside it had grown but half an inch. And this disparity, as was shown in due course, would be retained throughout the life of the trees. The seedling that sprang up rapidly and showed vigor from the start had potentialities of a giant tree; while the weakling beside it was prenatally doomed to remain forever a dwarf.

The nuts produced by the Paradox walnut were so few in number that Mr. Burbank was enabled to plant them all and to note carefully the characteristics of the seedlings that grew from them. He observed that about one-third of these seedlings revealed the characteristics of the Persian walnut, one of their grandparents; that another third tended to revert in the opposite direction toward their black-walnut grandparent; and that the remaining third were intermediate in character, reproducing more or less closely the characteristics of their hybrid parent.

It is interesting to note that Mr. Burbank recorded this observation in his printed catalogue of 1898, in offering the nuts of the Paradox walnut for sale.

This observation regarding the hybrids of the second filial generation is substantially in accord with what has since become famous as the Mendelian formula, which at that time was quite unknown to the scientific world. The formula had indeed been discovered by Mendel as long ago as 1863, but the paper in which he announced his discovery remained quite unknown until it was brought to light in 1900 by Professor Hugo De Vries and two other European botanists.

Mr. Burbank had observed the tendency to segregation and redistribution of characters in second-generation hybrids, which is the essential feature of Mendelian heredity not alone in the case of the walnuts, but in hundreds of other hybrids, and for many years his experiments have all been carried out with an eye to taking advantage of this observed natural phenomenon. But for many years after the death of Mendel (which occurred in 1884) Mr. Burbank was probably the only prominent plant experimenter in the world who clearly grasped the import of the law of inheritance, according to which hybrids of the first generation are relatively uniform and hybrids of the second generation enormously variable.

Mr. Burbank was too busy making practicable application of this discovery (which of course was made by him quite independently) to give thought to the publication of his observations. But such incidental publication as that just cited serves to fix his claim to independent discovery; and the long list of remarkable plant developments in many fields that were carried out at Santa Rosa and Sebastopol prior to 1900 by application of what is essentially the Mendelian principle very tangibly demonstrates the clearness with which the "wizard of Santa Rosa" had grasped this fundamental principle of inheritance.

I mention the matter here because it has sometimes been assumed that Mr. Burbank is a mere "practical" plant experimenter who has no knowledge of theoretical biology. Practical he surely is, and at all times he has considered that results are more important than methods; yet he never could have obtained the results that have made him famous had he not from the outset had the clearest comprehension of the subtlest principles of heredity, and the most sharply defined notions as to the methods through which these principles could be made available.

HYBRID ALMONDS

Perhaps it is not too much to say that the principle that hybridization of different species may produce new races sometimes entitled to specific rank was an original discovery made by Mr. Burbank and demonstrated by him as it has been demonstrated by no one else. Even to this day a good many biologists refuse to recognize this principle as an important factor in the evolution of species. Yet it is hard to doubt its cogency when one has had opportunity to examine the extraordinary new races that Mr. Burbank has thus produced.

We have just seen striking illustrations of this in the case of several species of nut-bearing trees. Other illustrations no less striking, though quite different in their specific application, are furnished by a long series of experiments made by Mr. Burbank in which the almond tree was one of the parents utilized. Some of these experiments consisted of crossing the almond with the Japanese plum; in other cases the strains of the almond were combined with those of the nectarine and the peach. In describing the fruit of this hybrid, Mr. Burbank says that it may be characterized as fairly intermediate between the fruits of the parent, yet on the whole the flesh of the peach and the stone of the almond respectively tended to be prepotent or dominant. This is perhaps what would be expected when we recall that the flesh is the specialized modern development in the case of the peach, and that the seed is similarly specialized and developed in the case of the almond. We have seen that there is reason to believe that prepotency or dominance is conditioned on newness of development, and the case of the peach-almond hybrid gives a measure of support to this theory.

In the second generation these hybrids of the peach and almond show an astonishing variation in size, rapidity of growth, and almost every quality of flower and fruit. As to the fruit, some specimens tend to reproduce the almond quality, others the peach quality; yet others combine the quality of the two fruits. The best of these second-generation hybrids bear fruits that are obviously peaches, even peaches of a fair quality, yet have at their center what is at once recognized as an almond nut with characteristic shell and seed.

In a word, these are almonds grown inside the peach,—a combination of obvious interest.

As yet this anomalous fruit has not attained commercial importance, because the varieties thus far produced are not peaches of the highest grade; neither do they bear almond nuts of the first quality.

It would be necessary to continue the experiment through successive generations, crossing the hybrids successively with peaches and almonds of the finest quality, in order to produce a peach-almond that could compete advantageously in the market with the varieties of peaches and of almonds already under cultivation. It is probable that ultimately this experiment will be carried out. It lies within the reach of any amateur who lives in a region where peaches and almonds will grow.

As to the almond itself, there is opportunity for improvement in the way of producing varieties that will bear large crops with regularity. The shell of the best cultivated varieties is perhaps as soft as is desirable, as it is liable to injury in shipping if it becomes too friable. But it might be possible to develop a variety that would have white shells, thus obviating the necessity for bleaching with the fumes of sulphur, which constitutes a somewhat expensive feature of the present almond industry.

Incidentally, it is worth while to note that the almond industry has attained a good degree of importance in recent years. As to the actual number of nut-bearing trees under cultivation, the almond heads the list, the trees in bearing in 1910 numbering 1,187,962, in addition to which there were almost 400,000 young trees not yet in bearing. The total marketable production of almonds in 1909 had a value of more than $700,000.

OTHER HYBRIDIZING POSSIBILITIES

When the economic value of nuts is under consideration, however, the palm must be yielded to the Persian walnut, which produced in 1909 a crop valued at $2,297,000. The number of walnut trees in bearing was less than the number of almond trees, but the value of the crop borne on an individual tree is much larger.

It should be noted that all but about sixty thousand of the Persian walnut trees in bearing in 1910 in the United States were in California. But the value of walnuts as a market crop has recently come to be appreciated elsewhere, and orchards of young trees are rapidly being introduced in other states, including, notably, Oregon and Mississippi.

Unfortunately, the Persian walnut is not a hardy tree. Yet it might be cultivated in many regions where it has hitherto been altogether neglected; and the results obtained in California suggest that it is well worth the attention of horticulturists throughout the southern and central regions of the United States. Moreover, there is a related Japanese species of walnut which is an exceedingly prolific bearer, and which is as hardy as our native black walnut.

Mr. Burbank has experimented in hybridizing this tree with the American walnuts. The results were interesting, in that the hybrids proved exceedingly variable, but they were not commercially important. It is certainly worth while, however, to extend these experiments, and it is not unlikely that the Japanese walnut may prove a valuable acquisition if its strains are blended in just the right way with those of the Persian walnut.

Until recently very few people in the eastern United States have thought of nuts of any kind as a crop for cultivation. Now, however, it is coming to be understood that various nut-bearers are proper candidates for orchard treatment, and capable of holding their own, or more than their own, as market crops, in competition with the best orchard fruits. This is notably the case with the walnut and almond and with the pecan nut, which is a relative of the hickories indigenous to the Gulf states.

The pecan flourishes as far north as St. Louis and the Mississippi Valley, in all the Gulf states, and along the South Atlantic seaboard.

The pecan nuts found in the market are chiefly the product of a few varieties that were found as "sports" in one region or another of the South, and propagated by grafting. They do not represent the art of the plant developer, but they illus-

AN INTERESTING VARIETY OF EVENING PRIMROSE

Mr. Burbank has experimented with many species of evening primrose. The remarkable specimen here shown, with flowers of extraordinary size, is a cross-bred and selected plant, some of the ancestors of which came from South America.

trate possibilities that are open to the experimenter. Mr. Burbank reports that he has seen nuts that he regards as undoubtedly hybrids between the pecan and the hickory. He suggests that a new nut of hardy quality might probably be produced by hybridizing the pecan with the shagbark hickory, and carrying the experiment forward along the usual lines of selection. The chief difficulty involved is that the trees are of slow growth, coming to maturity only after a good many years. Comparatively few persons have the patience to work under such conditions. Yet there is little question that such experiments will be undertaken in the near future, and important results may be expected in years to come.

It is desirable also to attempt to hybridize the pecan with the butternut and walnut and with the English walnut. Mr. Burbank suggests that if such hybridization could be effected, it may be expected that trees of rapid growth, similar to his hybrid walnuts, will be produced.

Not unlikely, he says, some varieties that tend to produce nuts at a very early age, like the hybrid chestnuts, may also appear as the result of such hybridization.

And in any event, it may confidently be expected that new varieties will give opportunity for wide selection, and for relatively rapid improvement in the quality of the nuts themselves. There is every reason to believe that the wild pecan will respond to the efforts of the plant developer, and that its descendants a few generations removed will take on qualities that the most sanguine experimenter of to-day would scarcely dare to predict.

As to the technique of hybridizing the various nut-bearers, there is no difficulty whatever. Chestnuts, walnuts, hickories, and pecans all belong to a tribe of trees characterized by bearing the staminate and pistillate flowers in separate clusters. To effect cross-fertilization, nothing more is necessary than to bring a bunch of staminate flowers, when the pollen is ripe, and brush them freely against a bunch of pistillate flowers.

To avoid contamination with other pollen, it will be advisable to tie a paper bag about the bunch of pistillate flowers, leaving it there a few days until the stigmas have passed the receptive stage.

DEVELOPMENT THROUGH SELECTION

You need not wait for the coming of another season, however, in order to begin work with the nut-bearers.

If you will stroll into the woods in your neighborhood this autumn and carefully examine the nuts fallen from different hickory trees, you will quickly discover that these vary greatly. Some trees bear uniformly large, thin-shelled nuts; others just as regularly bear small, thick-shelled ones. Here, then, is opportunity for immediately beginning experiments in selective breeding.

You must be forewarned, however, that the nuts taken from any individual tree have probably a wide range of variation as to their hereditary factors; so the seedlings grown from them will be by no means uniform. Some will probably grow much more rapidly than others, and when in due course they come to maturity, they will vary greatly as to the quality of their nuts.

But fortunately the seedlings may be fairly depended upon to show their qualities very soon after their cotyledons break the soil. The young plants that are of vigorous growth, with relatively thick stems and large fat buds, may safely be preserved as having future possibilities greatly exceeding those of their less thrifty fellows. Mr. Burbank assures us that it is not necessary to raise the entire lot of seedlings and await their time of maturing. You may safely follow his example in selecting the ones that grow rapidly during the first few weeks or months, weeding out the others.

But whereas you must expect a relatively wide range of variation, it of course is also true that on the average the seedlings grown from nuts of a tree that is a good bearer will be superior to those grown from the product of an inferior tree. So, as a matter of course, you will select for seed purposes only the very best nuts. In this connection, however, you must recall what has been said in the earlier articles about judging a plant by its total product rather than by the individual specimens.

A small individual nut from a tree that generally bears large nuts would have greater promise than a large individual nut from a tree that in general bore small nuts.

A "PAPER-SHELLED" WALNUT

As to the possibility of rapidly developing a new variety of nut through selection from the product of a single tree of unusual quality, Mr. Burbank's experience in the production of the Santa Rosa paper-shelled walnut is illuminative.

The tree from which this valuable variety was developed was a Persian walnut of unknown antecedents, that grew on a San Francisco street. Mr. Burbank noted that this tree bore many nuts that had exceedingly thin shells, and even some nuts that had shells that did not altogether cover the kernel of the nut,—suggesting in this regard the partially stoneless plum with which his experiments in the development of a race of stoneless plums had been undertaken.

Growing a large number of seedlings from nuts of this unusual tree, and selecting among them for different qualities, Mr. Burbank had presently a colony of English walnuts, some of which produced nuts so devoid of shell covering that the birds discovered their lack of armament and destroyed the kernels by pecking at them. The entire lack of shell proving thus a detriment, it was necessary to conduct the further experiments in selective breeding in the opposite direction, thickening the shell rather than eliminating it. But material for these experiments was at hand, and by careful selection Mr. Burbank soon developed a variety of walnut that had a shell of just the requisite thickness, to ward off the encroachments of the birds, yet so thin that it could be crushed in the fingers. The tree that produced nuts with this ideal quality of shell was an abundant bearer, and the nuts themselves were of good size, and their meat was white and of delicious quality. The nut was introduced under the name of the Santa Rosa Soft-shell or Santa Rosa Paper-shell.

Naturally this new variety soon became popular. But Mr. Burbank has been obliged to warn the public that they must be on their guard against the purchase of seedlings alleged to be of the Santa Rosa paper-shell variety. In point of fact, this variety, like other specialized tribes of the walnut, does not breed true from seed. It must be propagated by grafting; being precisely comparable in this regard to all of our best varieties of orchard fruits. Of course trees bearing nuts of excellent quality may on occasion be grown from these nuts, and exceptionally one of these trees may duplicate very closely the qualities of the parent tree. But other trees, grown perhaps from nuts borne in the same cluster, may show a wide variation, to the great disappointment of the misguided orchardist who expected them to show the qualities of their parent.

Fortunately, the grafting of the walnut represents no great difficulties for anyone who has facility in grafting orchard fruits. In cleft grafting it may be desirable to cut out a notch instead of splitting the stock. It is well to wax the parts thoroughly, and it may be desirable to give full protection from the drying effects of wind and sun by placing a paper sack over the scion while it is establishing its cellular bearings.

It has been found advantageous by many California orchardists to use the Burbank Royal walnut—which, as we have seen, is a hybrid between the eastern and western black walnuts—as a stock on which to graft scions of the Persian walnut. The Royal walnut has extraordinary capacity for growth, as above explained, and its root imparts something of its vigor to the scions engrafted on its stem.

Orchards thus established come early to bearing, and prove far more productive, as a rule, than those grown on the native roots of the Persian walnut.

As to the matter of early bearing, which is obviously of great importance in the case of commercial crop, Mr. Burbank has made experiments with the walnuts that are almost as interesting as his experiments with precocious chestnuts. He has not been able to make the walnut bear in its first season from seed, to be sure, but he has produced varieties that bear at the age of eighteen months. In general the varieties of walnuts that he has perfected tend to bear at an early age, and his experiments show that it is possible to lessen by several years the time of waiting for the seedling to come to fruiting age. Here, as with other qualities, there is great variation, and it is possible for the experimenter to select out and accentuate a quality—in this case precocious bearing—by the usual method of "line breeding." But at best patience is required in dealing with a plant which is normally of such slow growth as a tree.

ORNAMENTAL TREES

In the matter of stimulating the growth of a tree, there are some horticultural tricks that are worth remembering.

Fundamental among these, of course, is the matter of preparation and cultivation of the soil. Until recently a good many orchardists have assumed that it is useless to cultivate the soil about trees. But now it is well known that a tree responds as readily as does any other plant to proper treatment.

Mr. Burbank tells of an observation that furnishes striking evidence of this. He once observed the rings on an oak tree more than six hundred years old that had just been felled, and he noted that at a certain late stage of its development the tree had suddenly begun to grow much more rapidly than had been its wont for the preceding centuries. By counting the rings, he determined that the new growth dated from the year 1852. Inquiry showed that this was the time when the land had come under cultivation, and when for the first time the soil had been turned and rendered porous by the plow.

Thus it was demonstrated that cultivation of the surface soil materially affected the growth of a tree already more than five centuries old, stimulating it to new vigor and cellular activity.

This observation shows that even the oldest tree is not beyond reach of the benefits of soil cultivation; and the experience of any number of orchardists proves the immense benefit that young trees derive from such cultivation. It is probable that the foresters of the future will cultivate the soil about the roots of their timber-producing trees, just as the orchardist already cultivates the soil about his fruit producers. In any event, the grower of ornamental trees and shrubs in street and dooryard should on no account neglect to give his protégés the benefit of rich and regular cultivation of that soil for a number of feet about the trunk.

Among trees other than bearers of fruit and nuts to which Mr. Burbank has given much attention are the magnolia, Chinese maidenhair tree, and numerous conifers. A young sequoia ("big tree") under close observation is among the most interesting ornamental trees now growing in his garden.

Sometimes it happens that a tree that has a good root and leaf system fails to grow as rapidly as it might because it becomes "barkbound." Through some defect in the quality of its bark, the trunk is constricted and its growth prevented somewhat as if it were encased in an inelastic artificial jacket.

Where this defect exists, it may readily be

BURBANK HYBRID DAHLIAS.

The picture gives a good idea of the range of variation among the material on which Mr. Burbank is now working. Here are fascinating possibilities of development in many directions. Some very striking and popular varieties will doubtless result from the further utilization of this material in Mr. Burbank's gardens.

remedied by making longitudinal slits with a knife at intervals about the trunk, beginning each slit as high as you can reach, and carrying it to the very root of the tree.

Mr. Burbank has always in his pocket a large jackknife with which he can render timely aid to any tree that seems to his keen eye to be suffering from the tightness of its jacket. In the experiment grounds at Sebastopol you may see many trees that have been treated thus in the past, and most effectively, as evidenced by the broad strips of new bark, each spreading from the original track of the knife blade, and now united by a visible scar with the old bark which it so advantageously supplements.

You will do well to watch your trees of every kind with the thought in mind that they may be bark-bound, and you may give them relief and greatly facilitate their growth with a few strokes of your knife blade.

Grafting and budding are of course processes that require more skill. The details as to these were given in the chapter on orchard fruits. I would again remind the reader, however, that the process of grafting may be applied with equal advantage to trees and shrubs of almost any species, as well as to woody vines. You may, for example, make over a climbing rose by grafting it with buds taken from some thrifty vine. Or you may transform an ill-shaped and weakly shrub into a symmetrical and vigorous one by grafting healthy scions on its ill-nourished branches.

It is not as well known as it should be to gardeners and orchardists that the leaves of a plant are the seat of the essential laboratory in which hydrogen and oxygen and carbon are compounded to make living matter, and that the leaf system of tree or shrub is directly responsible for the growth of the root system. The protoplasm and starch and woody fiber that go to make up the root and enable it to grow and extend its ramifications are first compounded in the leaves, and are sent down through the cells of the cambium layer of the bark in return for the watery sap that the root system collects as raw material and sends up for compounding in the wonderful leaf laboratories.

There is, in short, the closest interdependence between leaf system and root system in the case of every plant; and this is strikingly shown by observation of trees and shrubs. If a tree has a healthy leaf system you may be sure that it has a good root system.

We have noted in the case of the walnuts how an inherently vigorous root system of a hybrid variety may stimulate the development of the leaf and branch system. An opposite illustration of the co-operation between branch and root is given when a very vigorous scion is grafted on relatively weak roots. Here the vigor of the top may give such stimulus to the root system that it keeps pace with the growth of the visible parts of the tree, far surpassing the limits it would have attained had it been left in partnership with its original aërial stem.

A striking illustration of this is furnished by a splendid elm tree that grows beside Mr. Burbank's old homestead at Santa Rosa.

This fine tree is in reality only fifteen or sixteen years old, although it matches in size other elms that are approaching the half-century mark. The explanation is found in the fact that the tree has grown from the branch of a natural hybrid elm. The parent tree, which Mr. Burbank declares to be the largest elm he ever saw, grew near his old New England home. When visiting his old home some sixteen years ago, he cut a twig from this hybrid tree and brought it with him to California. The twig was grafted on the root of a California elm, being implanted only a few inches above the ground, so that the scion ultimately furnished the trunk and all the branches of the tree. Casually observing this wonderful elm to-day, you would never suspect that it is not growing on its own roots; but careful inspection shows that the bark of the tree on one side is of slightly different texture for a few inches from the ground, and that there is a barely visible line of demarcation where it connects with the contiguous bark of the main trunk above.

In a word, everything visible except these few inches of bark just above the ground level is hybrid elm of New England ancestry; whereas, of course, the entire root system is California elm. But the coalition has proved a most happy one, as the exceptional size and vigor of the tree amply demonstrate.

There is a lesson in that grafted elm that anyone who has to do with ornamental trees or shrubs, or for that matter with forest trees, may advantageously take to heart.

PART III

BURBANK'S METHODS AND THE HUMAN PLANT

CHAPTER XI

THE BREEDING OF MEN

IT is worth much, by plant eugenics, to breed the spines from the cactus, and thus, at one stroke, rid the world of a plant enemy and give it a new plant friend.

But it is worth more, who shall say how many times more, to breed strength of mind or strength of body into a child—to breed out those qualities which might make the child a menace and to breed in those which make him a useful citizen and a successful individual.

It is the purpose of the ensuing chapters to deal with the subject of race betterment and self-betterment through the application of the laws of heredity to mankind—to study Luther Burbank's amazing success in plant eugenics with an eye toward its application to the practice of human eugenics.

Fitly to introduce the subject, let me tell the story of how, through the practice of eugenics, an obscure German bishop became the father of kings.

It is a story with all the elements of romance, but it is sober history.

At the outset, the tale concerns seven brothers who, along in the sixteenth century, inherited a small ducal estate on the borders of the Black Forest. The estate included the free Hanseatic city of Lüneburg, and was large enough to have some significance in German politics if undivided. But the brothers realized that if each were to claim a share in the estate its divided fragments would have little importance either severally or collectively.

The brothers were all talented and ambitious men, but they had a sense of family obligation that took precedence over their several ambitions. So they held a family conclave and decided that only one of their number should marry. The lot fell on the sixth brother, who accordingly chose a wife and in due course had a family of children. The remaining brothers worked and warred in the interests of the family estate with no reward except the consciousness that they had added prestige to the family name.

The children of the sixth brother made among themselves the same compact that their father and uncles had made. The duty of transmitting the family name devolved upon one Ernest Augustus, Bishop of Osnabrück. In that day an ecclesiastic might be a warrior as well, and the growing influence and success of the Bishop of Osnabrück enabled him to win for his wife a very extraordinary woman, Sophia of Palatine. The son born of this union inherited the original estate with sundry accretions, and his mother believed him destined for great things.

But a brother of the Osnabrück Bishop had

ROWS OF HYBRID AMARYLLIS

The flowers making up the main rows in the center of the picture, are hybrids produced by crossing the crinum and amaryllis. The view shows a section of Mr. Burbank's garden at Sebastopol.

broken his compact and also married, and he had a daughter, whose advent brought consternation to the family. Sophia of Palantine never forgave her niece for being born; but she solved the dilemma by marrying her own son to said offending niece, his cousin. So the family interests were again united.

Thus it appears that the family of the seven ambitious brothers was a dwindling company in the two generations that succeeded their compact, —and expressly because of their compact. In modern terms this seems a case of race suicide. But it may properly be interpreted in a yet more modern phrase.

What the ambitious brothers and their successors had done was to practice the art of eugenics in three important phases.

They had (1) restricted the number of descendants, through preventing the birth of supernumerary children; (2) they had wisely selected able mates for the procreating member of the family; (3) and they had concentrated the family estates and talents by judicious inbreeding—that is to say, by the union of cousins.

Now note the sequel of this remarkable practice of eugenic principles. The son of the erstwhile Bishop of Osnabrück and his brilliant wife became King of one country (George I of England), and their daughter became Queen of another (Sophia Charlotte of Prussia). Their direct lineal descendants to-day occupy the thrones of England, Germany, Russia, Denmark, Norway, Greece, and numerous minor principalities. As a direct sequel of that conclave of the seven ambitious brothers, their little estate became the cradle of monarchs. The self-abnegation practiced by the six brothers bore fruit that exalted their family from the control of a petty dukedom to the rank of kings and emperors.

And it was no blind chance that brought about this extraordinary advancement. It was the conscious application of laws of heredity which are followed all over the world in the breeding of domestic animals, but which have been for the most part ignored in breeding men. To-day the word eugenics is heard on every side and the idea for which it stands is in the air. It is a new word, and most people perhaps suppose that the idea is also new. But this is fallacious. I have cited the case of the seven brothers—a perfectly authenticated historical case which will further claim our attention in a later chapter—to give tangible illustration of the fact that practical eugenics as applied to the human race is no new art.

The new thing is merely that nowadays we should begin to think it worth while to apply this art to humanity in general, whereas hitherto it has been reserved for the breed of kings.

NEW KNOWLEDGE FROM PLANT BREEDING

It is true, however, that we have gained in recent years a great deal of precise knowledge as to the laws of heredity and as to their practical application. In particular, it has come to be recognized more and more fully that the same laws of heredity apply to all living creatures, and that correct inferences may be drawn from observation not merely of lower animals, but also of plants, as to the application of the laws of heredity to humankind.

This is peculiarly fortunate because plants offer in many ways better opportunities for observation than do animals. The fact that plants may be grown in enormous quantities, often maturing in a single season, gives opportunity for conducting experiments on a comprehensive scale, and sometimes for the discovery in the course of a few years of laws that might have required long periods for their elucidation had observation been confined to the direct breeding of the human race, or even to the breeding of the most prolific domesticated animals.

Everyone is aware that Luther Burbank has conducted experiments in plant breeding on a more comprehensive scale than any other experimenter, and that he has operated with a large number of individuals. His work has had to do with members of the vegetable kingdom of every type, and he has ceaselessly carried out his experiments, seldom having less than three thousand different ones under way, year after year, for a period of almost half a century. Naturally he has accumulated a vast fund of information, and this has now become available to the general public and to plant breeders through the official publication of his methods and results.

I have had opportunity to study the entire record of Mr. Burbank's work in manuscript, and to confer personally with Mr. Burbank himself as to all its details. I have been profoundly impressed with the importance of this work not only in its direct bearings on horticulture and agriculture, but in its application to the breeding of the human plant—a subject, it may be added, in which Mr. Burbank himself is intensely interested. It has seemed worth while to suggest in detail the application of Mr. Burbank's methods—guided always by their proved results in the vegetable world—to the question of the improvement of the human race, with particular reference always to the needs of the individual reader in everyday life.

Such an attempt will be made in the following chapter. I have thought that the pertinency of the topic and its practical possibilities might perhaps be emphasized by citing at the outset the authentic anecdote of the seven brothers who, with rare prevision, more than two centuries ago, forecast the Burbank methods in some at least of their most important applications, and in so doing exalted their family to the foremost place not merely in one nation, but in many nations. With this family of king makers we have no further present concern; but we shall have occasion to examine their pedigree more in detail in another connection, since it gives graphic illustration of certain laws of heredity that are of cogent interest to all of us.

BURBANK METHODS IN OUTLINE

In the present chapter I purpose to outline the broader principles of the Burbank methods, with mere suggestions as to their application along various lines that will be given detailed treatment in successive chapters.

Mr. Burbank himself has very explicitly stated that the essence of his method is rational and persistent selection. In a comprehensive experiment in plant development he (1) selects parent forms to be mated, and then (2) selects the best individuals among the progeny, and if necessary remates these to bring desired characters into the hereditary strain. When the right combinations have been produced, he (3) continues to select the best individuals, generation after generation, now practicing inbreeding instead of cross-breeding that the desired traits may be accentuated by repetition.

Casual observers of Mr. Burbank's work have been impressed with the early stages of this line of experimentation, somewhat to the oversight of the later stages. The hybridizing of species brought from widely different regions of the world is a somewhat more spectacular process than the continued inbreeding or "line breeding" of a given race, since the latter process seems to consist of nothing more than the selection of the best individual specimens generation after generation.

But in Mr. Burbank's opinion this process of line breeding through which specialized qualities are accentuated is no less important than the earlier process of cross-breeding; and in making application of the method to the human plant we must bear this constantly in mind.

SELECTION OF PARENTS

In the great majority of cases, indeed, nothing of real importance could be accomplished were the experiment carried no further than the first mating or hybridizing of the individuals selected to act as parents. Yet, on the other hand, right selection here is the condition of all future success.

Some of Mr. Burbank's most striking results have been attained through the hybridizing of species that were in many respects widely divergent. In particular, he brought together species from widely separated geographical territories, and thus gave opportunity for the blending of diversified racial strains.

Examples in point are furnished by the vast numbers of experiments with members of the race of plums. Almost at the outset of his experimental work Mr. Burbank imported plums from eastern Asia, and began crossing them with various species of plums from Europe as well as those indigenous to America. Presently he had hybrid races on his experiment farm at Sebastopol that combined the racial strains of practically all known species of plums under cultivation.

More than that, he crossed the plum with the apricot, producing thereby his wonderful new fruit, the plumcot.

So striking have been the results of this mating of plums of diversified characteristics that more than sixty new varieties of plums, prunes, and apricots have been introduced by Mr. Burbank, constituting an extraordinary company of fruits that are revolutionizing the plum-growing and prune-growing industries all over the world. One-third of all the plums shipped from California are now Burbank plums, and the best of his new varieties are of such recent introduction that they have not as yet made their influence felt, as they must inevitably do in the course of the coming decade.

Other illustrations of hybridizing experiments through which Mr. Burbank has produced remarkable results—to mention a few almost at random—are given by his hybrid races of blackberries and raspberries, including the Primus berry, the Phenomenal berry, the white blackberry, and the thornless blackberries; the Paradox and Royal walnuts, combining the traits of Persian walnut with those of the California black walnut in one case, and of the eastern species of black walnut with the Californian in the other; and in the Shasta daisy, which combines the characteristics of three species originally inhabiting Europe, America, and Japan, respectively.

AMERICA—THE RACIAL MELTING-POT

It is obvious that here in America we are bringing together, thanks to the extraordinary immigration of recent years, representatives of the human species of many races and from all regions of the globe. In the nature of the case, these newcomers will ultimately intermingle, and thus there will be accomplished, on a broader and more comprehensive scale, some such blending of the strains of different human races as Mr. Burbank has accomplished in the case of the different races of plants.

The question naturally arises as to whether the remarkable results that Mr. Burbank has produced in developing improved races of plants are likely to be duplicated in the case of the human plant here in America. Offhand it might seem that such should be the case. But before indulging in too optimistic an augury it is well to consider two or three complications.

In the first place, it must be recalled that Mr. Burbank imports only the best examples of the various species with which he experiments. He thus breeds from selected stock. But it is well known that a large proportion of the immigrants that have come to the United States in recent years are not the best representatives of their various races. On the contrary, they include a large proportion of inferior representatives.

Without dwelling at length on the matter here, it must be obvious that this introduces a compli-

ONE OF MR. BURBANK'S NEW VARIETIES OF GIANT AMARYLLIS

Some new varieties of the giant amaryllis have blossoms almost a foot in diameter. The sturdy qualities and prolific flowering of the plant are well illustrated here.

cation of more or less serious import. Mr. Burbank would not expect to improve a race of plants by introducing stock of an inferior type. As a general proposition, that seems axiomatic. But, on the other hand, it must be recalled that Mr. Burbank frequently finds it necessary to utilize a stock that is in many ways inferior, in order to take advantage of some one desirable quality of that stock.

A case in point is furnished by the new races of wonderful stoneless plums which Mr. Burbank developed by breeding from an originally wild plum of Europe which was small in size, and so acrid as to be practically inedible, but which had the essential quality of bearing a kernel with only a remnant of a stone.

This might very justly be regarded as an abnormal plum, and as a very perverted or retrogressive and altogether worthless example of its tribe. Yet its one quality of stonelessness—in itself an abnormality from the standpoint of plant economy—was so important that the strains of this little plum have been combined with those of a great variety of the most aristocratic plums in Mr. Burbank's orchard. And it has been found possible to breed into the hybrid progeny the good qualities of the aristocratic plums, while retaining the quality of stonelessness as the only reminiscence of the vulgar and perverted ancestor.

Is it not possible, then, that the immigrants who on the whole seem of undesirable type may have racial characteristics that will advantageously blend with the traits of the American race for the betterment of posterity?

It has been suggested, for example, that the Mediterranean races have the inherent love of music and the arts ingrained in their racial stock, and that this artistic sense may remain as a permanent endowment of their descendants in America when their less desirable physical and moral characteristics have been bred out of their progeny by mingling with the better strains of the American race, somewhat as the undesirable qualities of the little stoneless plum were bred out of their progeny in Mr. Burbank's gardens, while the one desired quality of stonelessness was retained.

Obviously this possibility must modify somewhat our verdict as to the possible outcome of the great mingling of races that is taking place in America to-day.

BREEDING FROM THE UNFIT

Let it be recalled, however, that the preponderant influence must be good if good results are to be attained. We cannot hope to assimilate too large an increment of foreign blood. More than fourteen hundred thousand immigrants came to the United States in 1914. Of those that came from southeastern Europe more than thirty-five per cent were illiterate. It is a serious question whether the American stock can amalgamate so high a percentage of foreign elements without deterioration.

Another complication that cannot be overlooked is furnished by the fact that the less desirable members of the population are observed to be far more prolific than are the superior members.

This obviously runs counter to Mr. Burbank's method in the development of improved races of plants; for it goes without saying that he chooses the best individuals in his plant colonies for crossing when he is endeavoring to improve a given race. Yet here again there are qualifying elements. It may be contended, with good reason, that the American race is a highly developed stock, so that there are elements of good in even its worst examples. One can never be sure, then, that the progeny even of individuals of undesirable traits may not show reversion to the better strains of their ancestors.

We must recall that every individual has a vast coterie of ancestors who in the aggregate represent a great variety of traits. You can probably recall your four grandparents, for example, and a moment's reflection will convince you that they differed as to their inherent qualities. And each of them tended to transmit his or her qualities to you, their common descendant.

Still more complicated would seem your heritage if you could know your eight great-grandparents. And when you reflect that the generation back of them numbered sixteen individuals and their parents thirty-two, the case becomes still more complex.

In a word, your ancestors increase in a geometrical ratio, and at a remove of only ten generations they number more than one thousand individuals. According to the most fundamental law of heredity, each individual tends to transmit all of his or her traits, and a moment's reflection shows that the ancestral tendencies that are struggling for mastery in the germ-plasm of any individual are multitudinous.

It is obvious that many of the traits involved must be mutually exclusive, and that hence any given individual must have almost numberless latent qualities that may never be tangibly revealed.

We shall have occasion to make fuller reference to this aspect of the subject in a moment. Here I wish merely to point out that no two individuals even of the same parentage show precisely the same combination of characters, and that the probability of bringing out any given trait obviously increases with the actual number of progeny.

As a tangible illustration, Mr. Burbank has himself called attention to the fact that he was his father's thirteenth child, and that no one of the dozen children who preceded him manifested any exceptional aptitude for horticultural pursuits. There are numberless cases in history where the man of genius appears as a later member of a mediocre fraternity. So we must recognize that the full racial opportunities of any given strain are not likely to be realized if the progeny are restricted to two or three individuals in a fraternity.

At first sight, then, it might seem that the enthusiasts who have prated about race suicide, and urged on humanity in general the duty of having large families, were justified. And indeed, Mr. Burbank's method of growing vast numbers of seedlings, in order to select the best, may be said to be corroborative.

It must be recalled, however, that Mr. Burbank has the option of destroying all of his seedlings, and that he commonly preserves only a few among the thousands.

Obviously this part of the plant breeder's methods cannot be applied to the human plant, and hence we are debarred from giving indiscriminate approval to the method of quantity production as applied to human beings.

What we are justified in saying, however, is that quantity production applied to the better classes of the community would be highly beneficial. It should be remembered that Mr. Burbank applies the principle of quantity production not indiscriminately, but to the best individuals. He could never produce the improved varieties for which he is famous were he to breed only from undesirable members of the colony, even though he germinated seeds by uncounted millions.

AID FROM GALTON'S LAW

In point of fact, it is necessary, in order to gain a clear understanding of the matter, to supplement what was just said about the multiple ancestry of each individual with the explicit statement that the major part of the qualities that are likely to find expression in any given case has been tangible in the immediate ancestors.

According to an estimate made by the late Sir Francis Galton, and hence sometimes spoken of as Galton's law, each individual inherits half his tangible traits from his parents, one-quarter from his grandparents, one-eighth from the great-grandparents, and so on in decreasing ratio.

In accordance with this rule, it is clear that only a very small portion of the tangible traits of any individual will have been inherited statistically from ancestors more remote than the great-grandparents. So in practice we are fully justified in saying that a person whose immediate ancestors are known to show a preponderance of undesirable traits has *bad* heredity, even though it can be shown that there were persons of the most commendable character among his remote ancestors.

In practice, then, it is possible for Mr. Burbank to determine pretty accurately what will be the main characteristics of the progeny of any given cross from observation of the parents and grandparents alone; yet it must never be forgotten that as regards some quality that may be vitally important there may be reversion to a remote ancestor.

The really vital question is whether, in practice, there is any definite guide as to this matter of the inheritance from remote ancestors of traits that are not manifest in the immediate ancestors.

Fortunately this question may now be answered in the affirmative. The new knowledge that makes this possible was gained primarily through the study of inheritance in plants.

Thus Mr. Burbank early discovered that when he hybridized two plants having different qualities the progeny of the first filial generation were relatively uniform in character, but that their progeny showed a very strong tendency to variation, some of them reverting toward one parent and others toward the other, and still others showing a new combination of the traits of the parents.

It was by following up the clews thus given that Mr. Burbank was able to make many of his most important plant developments.

As an illustration, Mr. Burbank crossed a partially thornless bramble that had been discovered in the eastern United States with the ordinary thorny blackberry, and produced a race of hybrids all of which bore thorns. But in the next generation a certain number of the progeny were thornless; and some of them combined with thornlessness the good qualities of fruit-bearing of their thorny grandparent.

On the same principle, Mr. Burbank produced his stoneless plums, white blackberries, and numerous other new plant developments.

MENDELIAN HEREDITY

The discovery that second-generation hybrids tend thus to recombine the characteristics of their grandparents in new combinations has been made even earlier by an experimenter whose work for the time being was ignored, but who subsequently came to posthumous fame through the rediscovery of his work about the beginning of the present century. This was the Austro-Silesian monk, Mendel. He had not only made independently the discovery that had meant so much in Mr. Burbank's work, but he had followed it out with numerical computations that gave him a very definite notion as to the exact way in which the divergent traits of any given pair of parents would be combined in their descendants.

Mendel's work was chiefly done with the garden pea, and he dealt with qualities that are mutually exclusive—large size *versus* small size, for example, in the case of the pea, or yellow pods *versus* green pods, or pink flowers *versus* white flowers.

To state the simplest case, Mendel found that when a tall race of peas is crossed with a short race the progeny are all tall; but the quality of shortness, although for the moment suppressed, is not lost, but reappears in about one in four of the progeny of the next generation.

A GIGANTIC BULB

The bulb that Mr. Burbank holds, is a hybrid specimen produced by crossing the crinum and the amaryllis. This specimen has not shown flower-bearing qualities commensurate with its size, and it is about to be discarded.

Mendel spoke of tallness as " dominant " in the case of the pea and of shortness as "recessive," and these terms are so convenient that they have passed into current usage. The essential thing is that the recessive trait, if its elements are present in the germ-plasm of an individual, will *inevitably* reappear in a percentage of the offspring of that individual under certain conditions; and it has been found that this fact is highly important from the human standpoint, inasmuch as there are certain human traits that show the phenomena of dominance and recessiveness in inheritance.

This is particularly true, for example, with defects of the brain and nervous system which may manifest themselves in subnormal mentality. There is a growing body of evidence to show that mental normality is dominant to mental abnormality, in the Mendelian sense of the word. Hence, when a perfectly normal individual is mated with one of subnormal mentality, the offspring will probably be normal; but these normal offspring, carrying the mental defect as a recessive trait, if mated with other individuals of similar heritage, may have progeny about one-quarter of whom are of defective mentality.

As an illustrative example, I may cite a case that came very recently under my observation. I was asked to examine a boy of ten who was obviously abnormal, and who on examination proved to be feeble-minded. His parents were not only normal mentally, but were both persons of exceptional ability, the father being a professor in a leading university, and the mother a woman of unusual culture and of a thoroughly common-sense type of mind. Inquiry revealed the fact, however, that in the families of both father and mother were members who were mentally unsound.

This taint of defective mentality was, then, a recessive trait in the germ-plasm of both parents; so it was almost a foregone conclusion that about one in four of their progeny would show some form of mental abnormality. In point of fact there were three children, two of whom were sound of mind and of unusual ability, the third being the defective child just referred to.

It goes without saying that this man and woman, however well suited for each other in all other regards, should have been debarred from marrying by the fact that they both carried latent strains of mental abnormality in their heredity. But it is only in the most recent times that anyone has understood the danger involved in such a union.

COUSIN MARRIAGES

Now that we have a clearer insight, it is obvious that such a case as that just cited is precisely comparable to what takes place when Mr. Burbank endeavors to fix and accentuate a quality by what he commonly speaks of as line breeding—that is to say, by the union of individuals having the same hereditary tendencies.

When, for example, Mr. Burbank discovered a specimen of the wild California plant called heuchera, or "wild geranium," that had a tendency to crinkle the edges of the leaves, he transplanted this specimen to his garden and carefully inbred its progeny generation after generation, selecting always the ones that showed the tendency of malformation of leaves, until presently he had a new race of heuchera with the most curiously convoluted leaves.

He could not have produced this result had he not interbred individuals that had the peculiarity of their heredity.

And this, indeed, is the typical method, as already suggested, by which Mr. Burbank fixes and accentuates a character, once that character has manifested itself. It was thus, for example, that the scented callas and verbenas and petunias were produced; also the improved Burbank varieties of almost numberless other flowers, fruits, and vegetables.

Of course, in the case of the human parents just referred to, the character contained in their germ-plasm was one which they desired to see eliminated, not perpetuated. But nature is quite impartial in the application of her laws of heredity. The same manner of transmission applies to desirable traits and undesirable ones. Indeed, it may be said that from the standpoint of plant economy some of the same qualities that make Mr. Burbank's new fruits and flowers most desirable are abnormalities. A double flower, for example, is much less well adapted to propagate its kind than a single one. Yet from the standpoint of the plant developer the double condition is desirable, as it enhances the beauty of the flower.

In the case of the human subject, however, the traits are adjudged by another standard, and are considered desirable only if they conduce to the welfare of the individual and the race. So we are usually concerned with the exclusion of undesirable qualities, and it is these that have hitherto been chiefly studied by students of heredity. But the fact that some at least of these qualities are transmitted along Mendelian lines gives clews that are invaluable.

The analogy with plant experiments shows how a defective trait that acts as a recessive factor in inheritance—any mental deficiency or susceptibility to tuberculosis—may be ingrained in a family and result disastrously. But, contrariwise, this same knowledge points the way to the elimination of such a defective strain.

Just as Mr. Burbank could not fix the abnormal quality of his wild geranium leaf without inbreeding, so the defective quality in the human subject is not likely to be fixed unless a person having the defect mates with another having a similar defect.

And this gives us a clew to a full understanding of the question of cousin marriage, regarding which there has been a good deal of difference of opinion among students of heredity in the past. In the light of the new knowledge it would appear that there is no necessary danger in such unions provided there is no defective strain in the family.

On the contrary, a desirable quality, even genius itself, may be thus accentuated, as we saw illustrated in the case of the family of the seven brothers.

If, however, a defective strain exists, the marriage of cousins brings together the two defective elements in precisely the way best suited to make them tangible in the offspring.

The practical lesson is that if there is a strain of mental defect or of susceptibility to tuberculosis—to name only two important conditions—in your family, it would be unwise for you to marry a cousin, although such a union might otherwise be not undesirable. The same objection applies to the union of individuals who have the same defect.

Thus it appears that the new knowledge of heredity does not necessarily tell whom you should marry, but may tell whom you should not marry. It is believed that a knowledge of Mendelian heredity will serve as a guide to intelligent couples in future, and that the happiness of the individual and the welfare of the race will thereby be vastly enhanced.

A fuller treatment of this aspect of the subject will of course be given in a later chapter.

CHAPTER XII

THE LAWS OF HEREDITY—THEIR DEFINITE MEANING AND INTERPRETATION

IT is traditional that one cannot gather grapes from thorns nor figs from thistles. The tradition embodies, by implication, the essence of the great central laws of heredity. This law is stated even more explicitly in the colloquial phrase "like produces like."

The sum and substance of the matter is that each and every living organism, be it vegetable or animal, tends to reproduce its own kind, and if we would get at the fundamental laws of heredity we have but to follow up the clew that this familiar fact gives.

We may see the principle illustrated to best advantage, perhaps, if we consider the lowly single-celled organisms, of which bacteria furnish a familiar type. These creatures, observed under the microscope, are seen to multiply by division, a single bacterium splitting to form two bacteria, each of which presently grows to the dimensions of the original parent, and then repeats the process of division.

Such a process of multiplication obviously passes on the substance of an organism to its descendants in so definite and tangible a way that there is nothing mysterious at all about the observed fact that children are closely comparable to the parent. It is inconceivable that they should be otherwise under the circumstances. The basal fact of heredity, then, observed thus as it were at its source, seems not in the least mysterious, but a mere matter of fact.

When we reflect that complex higher organisms are made up of groups of cells aggregated and differentiated to perform specialized functions, and that all growth takes place through cell division, it will be clear that the distinction between the single-celled organism and the complex higher organism is not as radical as might at first thought appear. Each individual even of the highest forms of life, including man himself, begins existence as a single cell and grows and develops only through the countless redivisions of that cell.

There is, however, a highly important modification to be noted in the fact that the cells of the higher organism become differentiated into divergent groups, capable of performing different functions. And, from our present standpoint, the thing to be particularly noted is that the tissue serving the purpose of reproduction of the species is segregated; and that this segregation takes place, in the case of higher animals, at a very early stage of the embryonic development of the individual.

THE CONTINUITY OF THE GERM-PLASM

The full significance, from the standpoint of heredity, of this segregation of the germ-plasm has been appreciated only within comparatively recent years. It was not until Professor August Weismann made special studies in this field, about thirty years ago, that the subject prominently attracted the attention of biologists.

Weismann had been struck by the fact that single-celled organisms, owing to the character of their reproduction by division, are, as he phrased it, "potentially immortal." They do not normally die, but rejuvenate themselves by division, a given individual becoming two, and these two presently becoming four, and so on in an unending geometrical progression, in which the descendants of any generation whatever might be regarded as representing the divided substance and personality of the original ancestor.

Weismann made application of this thought to the cells constituting the germ-plasm of the higher organisms. These, he said, pass on their substance and hence their potentialities from generation to generation much as does the protozoan; and this fact of the continuity and virtual immortality of the germ-plasm furnishes the simple and obvious explanation of the observed facts of hereditary transmission of qualities from one generation to another.

In each new generation a certain number of cells are differentiated to form body-plasm, and

QUANTITY PRODUCTION APPLIED TO THE AUSTRALIAN STAR FLOWER

Mr. Burbank was once asked to produce ten million star flowers (which retain their color when dry) for a Parisian milliner. He did not accept the commission, but this picture suggests that he might readily have done so.

ultimately develop to produce the entire organism with its varied members and bodily organs; but the remaining and essential portion of the germ-plasm maintains its integrity as germ-plasm, dividing to produce cells of its own kind, even as a bacterium or an ameba divides, and constituting an unbroken series of germ-cells linking the earliest ancestor of any line with the remotest descendant.

Parent and child are thus sprung from the same germinal stream, and in the broadest view they are not to be regarded as mother and daughter, but rather as sisters of the same fraternity.

The child has the qualities and characteristics of its parent not through any occult law of transmission, but because they both draw their qualities from the same germinal stream—the perennial stream of the ancestral germ-plasm.

It is important to get this idea of the continuity of the germ-plasm clearly in mind, for it furnishes the clew to a clearer understanding of the mysteries of heredity than would otherwise be possible.

MODIFICATION OF THE GERM-PLASM

It must at the same time be clearly borne in mind, however, that the stream of ancestral germ-plasm, which thus serves as the carrier of hereditary capacities from generation to generation, is not entirely beyond the reach of external influence, and does not remain absolutely unmodified throughout indefinite periods of time.

Even the bacterium changes its constitution somewhat in response to the conditions of temperature and nutriment in which it finds itself. By altering the medium and thus the food in which bacteria grow, it has been found possible to change their constitution so markedly that virulent types become relatively innocuous in the course of a few generations. Recent experiments suggest that the same thing may be accomplished by treating bacteria with ultra-violet rays, not sufficiently intense to destroy their vitality.

In a word, very marked modifications in the constitution of the single-celled organism may be produced by altered conditions of its tangible environment.

And these modifications are, as a matter of course, passed on to the descendants of the bacterium, inasmuch as these descendants constitute, essentially, portions of the parent form.

Exactly the same thing applies to the allied process of reproduction of the germ-plasm cells of the higher organism. Modified conditions of environment—changed conditions of temperature and of nutrition—may in some cases modify them, and such modifications will be transmitted to their offspring.

It is obvious that if such were not the case there could be no change in the structure or constitution of any given line of organisms from the remotest ancestor to the most recent descendant, inasmuch as the hereditary and permanent alterations of the body-plasm are contingent—according to hypothesis—upon modifications of the germ-plasm.

But as nowadays it is fully admitted that all forms of life have undergone change in the past—higher forms evolving from lower ones through modification—it is obvious that each stream of ancestral germ-plasm must have been more or less subject to influences that modify it.

As much as this at least is admitted by every biologist, whatever his view toward the allied question of the heritability of modifications that affect the body-plasm of an individual rather than the germ-plasm—a question, by the way, that will claim our attention in another connection, but which need not becloud our vision at the moment.

It must be understood, however, that the modifications that can be introduced in the germ-plasm in any given organism, through whatever environmental changes, are relatively slight as contrasted with the totality of qualities of that germ-plasm.

It is inconceivable, for example, that the germ-plasm of a brier should be so modified that its offspring will be bearers of grapes; or that the germ-plasm of a thistle shall become so transformed that the body-plasm sprouting from it in the next generation shall produce figs—to revert to the familiar illustration with which we set out.

To be sure, the vine that bears grapes and the tree that bears figs were doubtless originally as different from their present states as they still are different from thorns and thistles, but the graduations of modification through which the transformation has been brought about were infinitesimal in any pair of generations and have produced their effects only through the cumulative influence of myriads of generations.

If really radical transformations could be wrought in the germ-plasm of any organism in a brief period of time, the whole organic world would be topsy-turvy and there would be no laws of heredity to discuss—at least those laws would be something quite different from what they are.

Let us, then, supplement our idea of the continuity of the germ-plasm with the thought that this germ-plasm may be modified from time to time, but that the amount of modification permissible within any limited period is infinitesimal in comparison with the sum total of the qualities of the germ-plasm itself; which qualities, it may be added, represent the aggregate influence of past environments throughout vast and incomprehensible periods of time.

Luther Burbank has a capital phrase, to the effect that "heredity is the sum of all past environments." The import of the phrase becomes perhaps clearer if we think of it in connection with this picture of the ancestral germ-plasm—the tangible and definite series of cells directly linking every individual of any generation with the entire series of its direct ancestors.

CHICKEN VERSUS EGG

When we consider the germ-plasm in this light, its transmission of hereditary qualities seems in a sense simple and unavoidable.

But if we consider the matter a little more attentively it will appear that the germ-cell retains no small measure of mysteriousness. We agreed that there was nothing mysterious about the fact that the single-celled organism—say the bacterium—transmits its qualities, inasmuch as its entire body is bisected. But, although we have likened the germ-cells to a single-celled organism—which in point of fact it externally resembles—we cannot proceed far without noting the vital fact that the germ-cell carries the potentialities not merely of other germ-cells like itself, but of body-cells in endless profusion that go to make up the complex organism—let us say of a tree or of a man.

How is it conceivable that a germ-cell of microscopic size shall carry forward such potentialities, and carry them so definitely that they predetermine with absolute accuracy the form of every leaf on the tree, or the color of the eyes, the complexion, and the mental qualities of the man?

As to that, no one can give a really valid answer. That the germ-cell *does* convey these potentialities is familiar matter of fact. *How* it can convey them seems at first thought absolutely incomprehensible. But philosophers in all ages have puzzled over the matter, and there have been various theories put forward in attempted explanation.

There was, for example, a theory that gained popularity a few centuries ago, to the effect that all the individuals that are to descend (in successive generations) from any given germ-cell exist preformed in that cell. In a figurative sense, this fact might be said to be axiomatic. But the advocates of the theory declared that it was true in a literal sense also.

Out of this thought-tangle arose the famous quibble as to which first existed—the chicken or the egg.

Of course there was not the slightest scintilla of proof of any such mysterious ingulfing of infinite numbers of future organisms in the microscopic cell. And, equally, of course, the theory did not long persist.

MECHANISM OF THE GERM-CELL

Nevertheless, it is interesting to attempt to visualize conditions, even when the conditions themselves lie beyond the limit of microscopic vision. And when the germ-cell is thus visualized, one is forced to conceive of it as made up of infinitesimal particles of matter that in some way carry preformed the future organism that may grow from it. No one nowadays, however, supposes that this aggregation of infinitesimal particles in the germ-cell represents a replica of an adult organism. The conception is merely that there are particles of matter to represent each tissue or organ of the future organism, and that these are in some way so mutually disposed as to predetermine the future relations of the organs that will develop from them.

The modern physicist makes accurate studies of the sizes of molecules and atoms and of their numbers in a particle of matter comparable to the smallest germ-cell, that enables us to comprehend how very complex a structure this germ-cell may really be.

He tells us, for example, that there lies at the heart of the germ-cell a nucleus of infinitesimal size, yet his microscope reveals various physical structures within the nucleus which he calls "chromosones" because they are readily colored by stains. He believes that these "chromosones" have to do with the transmission of characters, yet he knows that they themselves must be enormously complex; and he makes calculations which show that these chromosones, infinitesimal though they be, are made up of millions of atoms. The very smallest particle of matter that the microscope reveals is estimated to contain "many times twenty billion atoms."

So the germ-cell may be in reality an enormously complex organism, containing thousands of particles, each one of which is made up of millions of atoms.

Such a computation, while it to some extent satisfies the mind as giving tangibility to the subject, does not in any proper sense fathom the mystery. It shows us that the germ-cell may be indefinitely complex; but it does not explain to us how its aggregated particles—which themselves are all grouped within the compass of a single microscopic cell—can definitely determine the size and form and color and peculiarities of the future organism into which that cell may grow.

In a word, the ultimate mystery of the transmission of traits through heredity, which is involved in the mystery of every higher organism, is an unsolved enigma which challenges the profounder insight of the future investigator. Here we must be content to take the facts of heredity for granted, and to point out the *modus operandi* of inheritance without attempting to fathom its precise meanings.

In a word, the mystery of heredity is linked with the mystery of life itself, and the two mysteries await a common solution.

THE FACTS OF HEREDITY

The facts of heredity, considered in detail, seem enormously intricate, yet they may be reduced to a few comparatively simple general classes. Indeed, the broad fundamental fact that each organism tends to reproduce its qualities in its offspring may be said to be the one all-compassing fact that includes every minor detail of hereditary transmission.

The full meaning of this great central fact of heredity was perhaps most comprehensively in-

A MINIATURE CHESTNUT TREE

This little plant, grown from the seed, is only six months old. Yet, as will be seen, it is in full bearing. Its burs contain several large nuts. Such precocity illustrates another of Mr. Burbank's notable triumphs in the breeding of hybrids.

terpreted by Professor Ernst Haeckel, when he formulated his so-called "gastræa" theory, in accordance with which each individual organism tends, in the course of its development, to reproduce the ancestral forms through which the race has passed in its evolutionary progress.

Thus the human embryo is at first a single cell and it passes in its embryonic development through stages in which it resembles such lower orders as fish and amphibia and lower mammals before it assumes the proportions and characteristics of the human being.

The characters are, of course, slurred over, and the reproduction of racial history is at best a blurred and epitomized one, yet the fact that the embryo does pass through such varied transformations, and that these at least roughly outline the racial history, is a highly interesting and important one, and may be said to exemplify the fundamental law of heredity in the most comprehensive way.

It is obviously a mere detail within this general law that an adult individual should sometimes develop a characteristic or an anomaly of some organ or tissue at the same age when the same characteristic or anomaly was manifested by a parent. Examples in point are furnished by those not familiar cases in which a cancerous growth develops at about the same age in parent and offspring, or in which a mental aberration similarly manifests itself.

Such manifestations of heredity are spoken of as "homochronous," but the big word scarcely adds anything to the observed facts.

The same may be said of the words "homotic" and "heterotopic" heredity, sometimes employed to express the fact that an inherited anomaly—say a tumor—may appear in the same tissues of the body of parent and offspring (homotic), or in another case in different tissues (heterotopic).

The fact is, as regards this particular matter, that a tendency to the development of a tumor may be inherited, but that the precise location of the tumor may perhaps be determined by the extraneous circumstances—say a local irritation.

The inheritance of special abnormalities of a precise and definite character—say a lock of white hair located on a particular part of the head, as a typical example—is likely to arouse surprise and to call forth comment on the mysteries of inheritance; yet rightly considered such a phenomenon is no more remarkable than the inheritance of all the ordinary characteristics that lead to what is familiarly spoken of as a family resemblance.

No one is surprised that the eyes or hair or complexion or stature or shape of nose or habits of mind in any individual strikingly resemble the same qualities of the individual's father.

In other words, the broad general facts of heredity are accepted as matters of fact without seeming to call for special comment. Stated otherwise, this is no more than saying that no one is surprised that grapes grow on grape vines and figs on fig trees. We would be astounded were the conditions reversed; and this evidences the almost axiomatic character of the great fundamental law of heredity, and its universal acceptance as a part of common knowledge.

MINGLING MODIFIED GERM-PLASMS

In all this, then, we are expositing the idea that the racial germ-plasm conveys the record of past environments and predetermines the characteristics and qualities of the organism that may grow from that germ-plasm. As thus far viewed, therefore, the facts connoted in the familiar phrase "like parent, like child" are scarcely more mysterious than the fact that successive cups of water dipped from the same stream should be like one another.

But there is a vastly complicating fact which we have thus far purposely ignored—the familiar fact, namely, that each higher organism is not the offshoot of a single parent, but a product of the union of two parents.

Be it plant or animal, every individual above the very lowest strata of organic-like owes its being to the union of two germ-cells. It represents the commingling of two strains of racial germ-plasm. Pollen grain unites with ovule in the case of the plant; sperm-cell with ovule in the case of the higher animal; and each type of cell conveys its own coterie of hereditary potentialities.

This is the essential and primary fact that complicates the entire situation. The fact of double parentage is one that will be seen at a glance to remove all simplicity from the formula "like produces like." For no two individuals are precisely alike; no two cells of the germ-plasm carry precisely the same ancestral traits.

The briefest consideration will suggest some, at least, of the complications that necessarily result when more or less divergent germ-plasms are commingled.

Of course, if two ancestral germ-plasms are too widely divergent they cannot commingle at all. The two organisms are then said to be mutually infertile. This was formerly supposed to be the case with most different species. Indeed, the test of capacity to interbreed with the production of fertile offspring was long considered to be the best test of specific identity. Nowadays we know, thanks largely to Mr. Burbank's experiments, that this test cannot be fully relied upon. Nevertheless, it is clear that only species that are somewhat closely related can interbreed.

Even where union takes place between members of the same species, however, there are sure to be some divergent traits that are more or less in conflict. It may chance even that there are numerous minor traits that are mutually antagonistic.

For example, to take the simplest and most familiar case, animals of the same species may differ radically in color. One guinea-pig may be jet black and another pure white. It is obvious, in such a case, that the offspring cannot be like both parents in color.

Here, then, is a complication that introduces an element of uncertainty into the otherwise simple law of heredity.

It is perhaps not too much to say that all questions of heredity center chiefly around the inquiry as to just what are the mutual relations of more or less antagonistic qualities when commingled through cross-fertilization.

HYBRIDIZATION AND VARIATION

At an early stage of his work in plant development, Mr. Burbank discovered that it is possible to hybridize species that are seemingly quite divergent, and that the results are often very striking. He brought together plants from different continents, and found that in many cases they would interbreed.

For example, he hybridized the Siberian raspberry with the California dewberry, producing a remarkable new fruit which he called the Primus berry.

Everyone is familiar with the conspicuous differences between a raspberry and a blackberry. To mention only one of them, the raspberry leaves its receptacle on the vine when picked, while the blackberry retains the receptacle as part of the fruit. It at once becomes an interesting question as to how these divergent qualities are harmonized in hybridized offspring.

In point of fact, inspection of the hybrid Primus berry shows that each parent strove to transmit its own peculiarity as regards this matter of the receptacle. The result is that the Primus berry, if plucked just at the moment when it is approaching maturity, acts like a blackberry, bringing away the receptacle as part of the fruit. But if the fruit is left on the vine until a little past the moment of maturity, it shows the property of the raspberry, leaving the receptacle on the vine, and coming away as a cup-shaped fruit. Here, then, there is a compromise in which it may be said that each line of ancestral tendencies makes its influence felt.

In general, it may be said that this case is typical. As a rule, the different traits of plants or animals that can be interbred are not so widely divergent as to be absolutely antagonistic, and the offspring is likely to show a blending of the traits. There are numerous cases, however, in which a compromise is not so readily effected, and in which one trait or the other seems for the moment to be predominant.

As an illustration of this, take the case of Mr. Burbank's white blackberry. If this is crossed with a black blackberry, the hybrid bush will bear only black berries; the tendency of the white blackberry to reproduce itself seems entirely subordinated.

But, although for the moment subordinated, the tendency to produce white berries is not lost from the germ-plasm of the hybrid. The proof of this is found in the fact that in the next generation a certain proportion of the progeny will bear white berries. This reappearance of a submerged trait in the second and in subsequent generations furnishes one of the most striking and interesting aspects of the entire subject of heredity.

THE PRODUCTION OF MUTANTS

Mr. Burbank had not proceeded far in his studies of hybridization before he discovered that the most astonishing segregation and redistribution of characters may take place in second-generation hybrids.

If he crossed two parent strains that were more or less divergent, he might find the traits of the parents variously blended in the hybrids of the first generation; but if he interbred these hybrids, he was almost sure to get in the next generation a conglomerate fraternity, showing the traits of the grandparental forms reassorted into almost every imaginable combination. More than that, there were likely to appear forms that diverged markedly from either of the grandparents.

It would seem that the mingling of divergent germ-plasms had made possible the rejuvenescence of ancestral traits that had long been submerged.

Mr. Burbank found that by carefully inbreeding individuals that showed the new or revived trait he could accentuate the quality and in many cases produce new varieties so markedly different from either of the grandparental forms as to justify his use of the term "new creations."

The only plausible explanation of such anomalies is that the qualities thus newly revealed and accentuated were traits that had been manifested by remote ancestors, but which had been subordinated and submerged through conflict with other more or less antagonistic traits in the ancestral germ-plasm.

So striking were the modifications that Mr. Burbank was thus enabled to produce at will through the hybridizing of divergent forms that he came to feel confident of being able to modify almost any form of plant life, and produce striking new varieties, provided an allied form could be found with which hybridization could be effected.

When the celebrated Amsterdam botanist, Professor Hugo De Vries, came forward with his theory of mutation, according to which a form of plant life may now and again diverge radically from its parent forms through "spontaneous" variation, constituting a new form of "mutation," Mr. Burbank was first to assert that such mutant forms were explicable as due to hybridization.

He asserted that he himself produced mutations at will through hybridization, and the long list of his plant developments afforded striking verification of his claim.

More than this, Mr. Burbank's experiments led him to believe that hybridization takes place among plants and animals in a state of nature

DWARF CHESTNUT TREE.

This reproduction of a direct color-photograph shows a bush-like tree that is a fine example of a Burbank hybrid chestnut. The workman who stands beside the tree is five feet seven inches tall. Note the abundant crop of nuts on the tree and under the tree. Gathering chestnuts becomes a simple matter when the trees are of this type.

much more commonly than had hitherto been supposed, and that such hybridization is often responsible for the production of new forms that may play an important part in the scheme of evolution. He believes, indeed, that hybridization largely accounts for the origin of those variations which Darwin had been content to speak of as "spontaneous," and which are recognized as the material with which natural selection works in developing new species.

MENDELIAN HEREDITY

The striking results in the production of new varieties through hybridization that Mr. Burbank had attained became known to horticulturists and biologists, and probably had an important share in preparing the world to look with interest on the experiments of the Austro-Silesian monk, Mendel, when the obscure report that this experimenter had published as long ago as 1863 was rediscovered just at the close of the nineteenth century.

Mendel, working chiefly with the garden pea, had paid attention (as we have already seen) to a few conspicuous characters regarding which different races of garden peas differ.

He had observed the mutual relations in the inheritance of such qualities as tallness *versus* shortness of vine, pinkness *versus* whiteness of flower, yellowness *versus* greenness of pod, etc., and had traced very definitely and with scientific precision the relations of these qualities in cross-bred plants of the first and second generations. In so doing he reduced to a definite formula the observation of the mingling of traits in the first generation and their redistribution and recombination in the second, which Mr. Burbank has observed to be so common a phenomenon with the great number of species with which he worked.

But Mendel went further. He formulated a theory as to the causes that operate to determine the relations of antagonistic characteristics when brought together through the mingling of divergent germ-plasms; and his theory was at once so simple and so satisfactory that it has now come to be accepted at least as a provisional hypothesis everywhere.

According to this theory, every tangible characteristic of any organism is determined by the mingling in the embryonic germ-plasm of two hereditary "factors" or "determiners," the juxtaposition of which is essential to the production of the character in question. If these factors represent the same quality, there will, of course, be no antagonism, and the quality of the resulting character will not be in doubt. But if, on the other hand, the two factors are antagonistic—one, let us say, representing a black berry and the other a white berry—the result may be that one factor entirely dominates the other, the subordinated character seeming to have no representation whatever.

But the factor thus submerged reproduces itself and distributes its representatives in the germ-cells of the next generation quite as freely as does the dominant factor. So there is an even chance that factors of the subordinate type will be represented in the germ-cells that are to produce progeny of a second generation.

According to the mere theory of chances, if we mix together indiscriminately a quantity of black factors and white factors in equal numbers, and pick out pairs of factors at random, it must result that in any *average* group of four pairs we shall find one pair of black factors, one pair of white factors, and two pairs of mixed factors.

If you will experiment with checker-men, drawing them in pairs from a mixed lot, you will be surprised to find how generally you approximate the formula, even when small numbers are in question.

NATURE'S GAME OF CHANCE

According to Mendel's interpretation, nature performs such an experiment whenever two germ-cells bearing antagonistic factors have come together, and the results of her game of chance are seen in the phenomena of what have come to be spoken of as Mendelian heredity.

Tangibly illustrated, the result is that when, for instance, a pea having a tall vine is crossed with one having a short vine, the offspring will be tall; but *their* offspring will be represented, on the average, by one tall vine (pure dominant) that will breed absolutely true, one short vine (pure recessive) that will also breed absolutely true, and two tall vines (mixed) that will not breed true because they contain factors both of tallness and of shortness.

The essential truth of the Mendelian formula has been demonstrated by thousands of observations, but a good many workers who have observed its application in simple cases have failed to realize the true bearing of the phenomena. The truth seems to be that it is only the comparatively superficial and newly acquired characteristics of any organism that still have sufficient flexibility to be experimented with by nature in this game of chance that we speak of as Mendelian heredity.

Stated otherwise, what we term Mendelian inheritance appears to be nature's method of testing out new qualities that are from time to time impressed on the organism through the influence of environment.

Some individuals of a certain strain of plants or animals chance to be subjected to influences that modify somewhat the color of flowers, the texture of hair, the size of body, or what not. An individual of this modified race presently interbreeds with an individual not so modified.

The important question is this: Is the modification beneficial to the species or otherwise?

The matter is put to an impartial test through the operation of Mendelian heredity.

All the immediate offspring present tangibly the modified character, but the unmodified character is given a hearing again the next generation. And if the modification is neither favorable nor unfavorable to the race, it may chance that two varieties, one showing the modification and the other without it, will continue to flourish in the same environment.

As a typical instance—taken at random—you may find gray screech-owls and red ones in the same brood.

If, however, the modification is favorable, the individuals possessing it will ultimately prevail over those lacking it, and it will be added to the regular equipment of the species. If, contrariwise, the unmodified character was better adapted to meet the requirements of environment, it will prevail, and the individuals having the modification will be weeded out.

A pure "recessive," as we have seen, carries no factors for the antagonistic "dominant" quality. Thus it may come about that certain traits of a given organism are absolutely eliminated from the germ-plasm of a fixed proportion of the descendants of that organism. Thus—anomalous though it seem—an individual may be of "pure" strain notwithstanding the fact that one of his grandparents was of different strain; and the known laws of heredity pretty clearly explain the anomaly.

This is the one really new conception in the present-day interpretation of the laws of heredity. The older idea was that any trait once impressed on the organism remains forever as a latent character in the germ-plasm, and is susceptible of being made tangible in some of the progeny under favorable conditions.

The laws of Mendelian inheritance show us that the factors of heredity may be so redistributed that individuals of the same parentage, and hence precisely the same heredity, broadly speaking, are radically different in their innate hereditary tendencies as regards some minor but perhaps not inconsequential qualities.

The new knowledge does not controvert the old rule that "like produces like," but it gives us new insight into the interpretation of that rule. In its practical bearing on the interpretation of heredity as applied to human beings, the new knowledge takes precedence in importance over all that has hitherto been known about heredity.

Until the Mendelian interpretation was available, no one could pretend to fathom the mysteries of atavism, much less to predict as to the probable recurrence of submerged ancestral qualities in any given generation.

But the Mendelian formula serves as a working hypothesis that enables us in many cases to predict with a fair degree of certainty what will be the result of the union of individuals of known heredity.

Thanks to this hypothesis, however, the laws of heredity in their application to the human organism now take on a definiteness that they hitherto have lacked.

MENDELISM AND INSANITY

As an illustration in point, let us note the results of some recent studies which give us new light on the heritability of that most pitiable of human afflictions, insanity.

It seems to be established that the forms of nervous instability that lay the foundation for insanity tend to act as Mendelian recessives in heredity.

It follows that if an insane person is mated with a perfectly normal one, the offspring will probably be personally normal, although carrying the factors of nervous instability in their germ-plasm. But if two individuals having this heritage are mated, even though both are personally normal, there will almost certainly be evidence of nervous instability in at least one in four of their offspring.

Consideration of the Mendelian formula, which has been fully stated in earlier chapters of this book, makes it clear why the examination of pedigrees, to determine whether heredity enters into the causation of any given case of insanity, must be extended beyond the first generation of the ancestry, and in collateral lines.

It will be recalled that a recessive trait makes itself tangibly manifest only when the factors for recessiveness are combined in the germ-plasm, uncomplicated by the presence of the opposite factors; and hence that the recessive traits always "breed true." This explains the observation of psychiatrists who report that, in cases under observation, where two persons both of whom are insane are mated their offspring all become insane.

It is obvious, then, that the question of selection of marriage partners for persons in whose families there is a strain of insanity is a highly important one. Mendelian heredity explains how it is possible that, in a fraternity whose parents were "mixed dominants" as regards the factors for mental instability, one individual may inherit a perfectly sound and normal nervous system, whereas an own brother or sister of this individual—even a twin—may inherit a nervous system so unstable as to invite overthrow.

This must be borne in mind whenever we consider the question of persons in whose families there are strains of insanity.

Unfortunately a recessive trait, in the case of a mixed dominant, may be so completely submerged that it gives no manifestation whatever of its presence. Yet it will come to the surface no less surely if this person marries with another mixed dominant. So the only safe rule in a case where there is known to be insanity in the family heritage is to avoid marrying into another family having a like defect.

It is obvious that cousin marriages under these circumstances would be peculiarly hazardous.

GRAFTING FRUIT TREES AT SEBASTOPOL

Mr. Burbank's assistants are grafting scions of choice varieties on old trees. Practically every tree in Mr. Burbank's orchard bears numerous varieties. Sometimes there are many hundred varieties on a single tree.

BREEDING FOR GENIUS

There is, however, another aspect of the subject of cousin marriages that must not be overlooked in the present connection. It is true that such unions involve the danger of accentuating strains of nervous instability in the family through combination; but it is also true that there is the possibility of accentuating nervous and mental characteristics that underlie genius itself.

In point of fact, the old tradition about the affinity between genius and insanity is not altogether without foundation. Men of the very highest type of genius, to be sure, are eminently sane; yet it would appear that there are certain attributes of sensitiveness of nervous organization, tendency to egoism, and almost preternatural energy that may occur from time to time in a family and may in some instances be combined in such a way as to produce genius, while in other instances they induce insanity.

To advocate the marriage of cousins in a family characterized by exceptional qualities of brain would, therefore, be in a sense hazardous, yet it might result directly in the production of men of genius.

A very good illustration of the possibility of producing a fraternity of exceptional individuals through the union of cousins who are themselves exceptional is furnished by the pedigree of Frederick the Great. In point of fact, this pedigree furnishes a striking illustration of close inbreeding not unlike that which Mr. Burbank practices when he would accentuate a desirable quality in one of his plant families. The case has double interest in the present view because, in considering it, we are brought back to the family of the seven brothers whose practical experiment in eugenic breeding was referred to in an earlier chapter.

It will be recalled that of the seven brothers only one married, and that in the succeeding generations the duty of transmitting the family name devolved upon one Ernest Augustus, Bishop of Osnabrück, who married an extraordinary woman, Sophia of Palatine. The child of this union was married to a daughter of the Bishop's brother, and these cousins were the grandparents of Frederick the Great and his distinguished fraternity.

When a chart showing the full genealogy of this extraordinary family is shown it appears that the father and mother of Frederick the Great were cousins; that both pairs of his grandparents in turn were cousins; and that his paternal grandmother was the sister of his maternal grandfather and cousin of his maternal grandmother.

In the third generation, of four pairs of ancestors, one pair appears in both paternal and maternal strains, so that there are only six persons, and two of the six are brothers; there being only five ancestral strains of blood represented, instead of the normal eight.

Here, then, is an extraordinary case of inbreeding, in which are combined the strains of many remarkable individuals; for in addition to those already mentioned the pedigree shows, in the third generation, two other remarkable women, Eleanor d'Olbreuze and Louisa Henrietta of Orange, the latter a descendant of the Great William the Silent and the only less celebrated Gaspard the Second.

The blood of William the Silent appears in three other strains of the pedigree, and that of Mary Queen of Scots in two strains.

In a word, there is scarcely an undistinguished male among the forty individuals who represent Frederick's ancestors within five generations; the fact that these are but forty, instead of the normal sixty-two individuals, in itself reveals graphically the extent to which the various strains of this distinguished ancestry are interwoven through an intricate web of inbreeding.

The progeny of this extraordinary experiment in eugenics reveal, in the generation upon which our attention is focused, not only Frederick II, one of that small select company of all time who by common consent are surnamed "the Great," but a brother Henry and a sister Amelia almost equally gifted, and a sister, Sophia Ulrica, who may be said to stand fully on a par in intellectual endowment with her illustrious brother, and who as Queen of Sweden was known as "the Minerva of the North," and became the mother of the famous Gustavus III.

INBREEDING FOR DEGENERACY

But lest too sweeping a conclusion be drawn from this remarkable example of inbreeding for genius, it is desirable that we should at once turn to another royal pedigree and observe the effects of inbreeding where the traits combined and accentuated are not preponderantly desirable ones, as in the case of Frederick the Great, but include also elements of mental aberration and physical and mental degeneracy.

Such a pedigree is supplied in the immediate ancestry of Don Carlos, the "madly depraved and cruel" scion of the Spanish royal house, a man who has been characterized as the most heartless and depraved individual in modern history.

A glance at a chart showing the ancestry of Don Carlos reveals that his father, Philip II, and his mother, Mary of Portugal, were at once first and second cousins, and that each ancestral strain leads quickly back to ancestors characterized as weak or cruel or mad.

Joana "the mad" appears twice in the third generation, and the insane Isabella four times in the fifth generation.

The inbreeding is so close and intricate that it would be difficult to characterize the relationship. In five generations there are only twenty-eight individuals instead of the normal sixty-two. Thus a profoundly neurotic strain is allowed to become overwhelmingly preponderant by repetition. As Dr. F. A. Woods has said, it was as if the sovereigns of that time were breeding mental monstrosities for a bench show. Their experiment shows the eugenic principle inverted.

But the feature of the pedigree of the depraved Don Carlos which chiefly concerns us at the moment is the fact that there appear in the table, mingled with the names of the weaklings, the mentally unbalanced, and the morally depraved, the names of several famous characters, including Charles the Bold of Burgundy, Maximilian I of the Holy Roman Empire, Ferdinand and Isabella the Catholics, and the Emperor Charles V. What further excites surprise is that the names of Ferdinand and Isabella appear again and again in the fourth generation, and that in the heritage of Isabella there seems to be an alternation of generations between insanity and genius.

This gives practical illustration of the affinity—above referred to—between mental aberration and genius of a certain type. It suggests further that genius and mental impairment follow the same law of inheritance.

There is a growing body of evidence to show that both views are valid. In recent years investigation has been made not only on the bad strains of royal pedigree, but on the heredity of genius and of insanity among people in general, and the result is that we are nearer an understanding of this hitherto obscure subject than ever before.

The puzzling thing has always been that the children of the man or woman of genius very commonly have no genius; yet that they sometimes seem able to transmit genius to their descendants.

No explanation of this anomaly was forthcoming until the recent studies gave a clew through the suggestion that genius is a unit character (or group of traits) which acts in inheritance as a negative or so-called "recessive" character.

It is pretty obvious, then, that we cannot always tell just what will be the result when representatives of families having neurotic strains intermarry. There may be cases in which it will be difficult to predict as to whether the children will probably be stable geniuses or persons of very unstable nervous system. But as the former are very rare or the latter very common, it follows that the chance of favorable results from a union that thus blends neurotic strains is far from favorable.

CHAPTER XIII

NURTURE *VERSUS* NATURE

REPORTS have recently come from New Zealand that tell a remarkable story about the Monterey pine. This tree is indigenous to California. It grows in very restricted regions, and the comparatively few individual trees that are now in existence are supposed to be reminiscent of a remote prehistoric flora. Indeed, the chief interest of the tree hitherto has been the fact that it is found in so restricted an area, and in such small numbers.

But now word comes from New Zealand that this tree has proved to have very remarkable qualities when grown in that country. Someone made the experiment of transporting the Monterey pine to New Zealand a good many years ago, and this change of environment appears to have had a most extraordinary effect.

Whereas the Monterey pine in its native country is practically valueless from an economic standpoint, it proves so remarkable a producer of wood in its new home that it has there received the name "The Wonderful Tree."

Reports tell us that the Monterey pine in this new habitat exceeds all other trees in rapidity of growth, and produces an amount of valuable lumber that is quite without precedent.

No species of pine in America produces lumber at a rate at all comparable to the records that come to us from New Zealand, telling of the extraordinary productivity of the Monterey pine, which in its native climate is of such slow growth and produces timber of such poor quality that it is not usually listed among timber-producing trees of economic value.

Now it is obvious that the transplantation of the Monterey pine from California to New Zealand can in no wise have affected the hereditary tendencies of the tree. Whatever capacities for growth and timber production are revealed by the tree in New Zealand must have existed as potential qualities in the seed that was taken to New Zealand from California. The change has not been brought about from hybridization or by selective breeding.

It is merely that a new environment—new soil, different climate—has taken a hand in the development of the submerged hereditary factors; and under these new influences the tree has been made to reveal possibilities that were hitherto unsuspected.

So the case of the Monterey pine affords a very striking demonstration of the influence of environment in bringing out unsuspected hereditary tendencies. It furnishes an object lesson in the power of nurture to supplement—and even, on

HYBRID MASSACHUSETTS ELM ON CALIFORNIA ROOTS

Note the different quality of bark at the base of the tree, representing the California stock, on which the twig brought from Massachusetts was grafted. The tree is only fifteen years old, and its extraordinarily rapid growth is ascribed by Mr. Burbank to the fact that the parent from which the twig was cut was a natural hybrid.

occasion, seemingly to supplant—the power of nature.

AN IMMIGRANT RHUBARB

But this very striking demonstration of the modifications in the life history of an organism that may be brought about through changed environment is by no means without precedent.

Something quite comparable has been observed, for example, when the migration has been effected in the opposite direction, the plant being brought from the southern hemisphere to our own northern latitudes.

The case of the eucalyptus tree, which takes on extraordinary capacities of growth in California, is perhaps not to be too greatly emphasized because this tree is also a rapid grower in its native Australian soil. But there are other plants that seem to reveal new possibilities, in particular when brought to California from the southern hemisphere.

As a typical instance, we may recall Mr. Burbank's winter rhubarb. This plant, when Mr. Burbank first imported it from Australia, had a stalk scarcely larger than a lead pencil. The sole value of the plant from an economic standpoint, and the thing that gave it chief interest for Mr. Burbank, was the fact that it had the habit of putting forth stalks in cold weather.

Lower temperature appeared to have the effect of stimulating it, just as high temperatures stimulate most other vegetables.

Mr. Burbank saw in this peculiar habit the possibility of producing a valuable market vegetable that would mature at times when the ordinary pie-plant is dormant. The expectation was verified. Under the changed environmental conditions of California, the winter rhubarb developed wonderfully, without hybridization, until its stalk was many times larger than the original plant from the antipodes. Meantime it retained its habit of putting forth stalks most abundantly during the period of cold weather.

But of course the winter season in California corresponds with the summer in Australia. So in putting forth its stalks in cold weather at Santa Rosa the plant was modifying its habit radically, as tested by the calendar. That is to say, it now puts forth its stalks in response to the stimulus of cold weather from November to January, instead of from June to August.

Here, then, was a case in which changed conditions of the environment, as marked by the most radical shift of seasons, sufficed to transpose the time of bearing of the plant, twisting it an entire half-year out of reckoning.

But meantime the hereditary clockwork mechanism within the cells of the plant, through which its time of development had been adjusted for the months of June, July, and August, still maintained its force; so the plant, thanks to this inherent impulse—and now operating in defiance of environing conditions—continued to put forth its stalks abundantly at its accustomed time, which now, under the changed conditions, coincides with the summer season.

The net result of these two sets of impulses was that the plant continued to be a "winter rhubarb," yet was now a "summer rhubarb" as well.

And by selecting for a few generations among the plants that showed greatest tendency to prolong the seasons, Mr. Burbank was able to merge winter bearing and summer bearing, bridging the gaps of spring and autumn, until his perfected plant, while he still designated it as a "winter rhubarb," was in reality practically an all-the-year bearer.

Meanwhile, by further selection, aided now by hybridization, it was found possible, thanks largely to the aid of the new environment, to stimulate the plant to such unwonted vigor of growth that the descendant of a plant which came to California with a pencil-sized stalk now produced a stalk comparable rather to a broom-handle, lifting its leaves several feet into the air, and fully meriting the name of Giant Winter Rhubarb.

ENVIRONMENT VERSUS HEREDITY

Here again, obviously, we are given a striking illustration of the power of environment to bring out concealed hereditary potentialities. We dare not suggest that environment has introduced new traits that did not exist in the hereditary mechanism of the plant. To suggest this would be to imply that environment may transform an organism in a single generation in a way so radical as to bid defiance to specific bounds; making the sequence of evolution a haphazard performance which we cannot believe compatible with the orderly progress of nature.

We are bound to believe, then, that when we see a plant transformed as to its tangible properties in a single generation, or in a few generations, through the influence of changed environment, we are witnessing the bringing out of suppressed tendencies, the realization of submerged potentialities, rather than the implantation and development of really new traits.

Making the interpretation specific, we must believe that the Monterey pine, which now in California is a tree of stunted growth, had ancestors that were rapid-growing mammoth trees. Through unfavorable conditions—the result, perhaps, of a glacial epoch—the tree gradually modified its habits of growth and perhaps preserved its life through such modification; but the hereditary factors for gigantic growth still existed in its germ-plasm, and awaited only a favorable opportunity to make themselves again manifest. The opportunity came when some chance seeds of the tree were transported to New Zealand, where it chanced that the conditions of soil and climate were such as to favor these long-submerged hereditary factors, giving them opportunity to prove their existence and their latent potentialities for development.

Similarly the small winter rhubarb, with its pencil-like stalks, as Mr. Burbank found it in Australia, must be regarded as the dwarfed descendant of some tropical plant of the elder day which had been forced to modify its manner of growth to meet altered conditions of climate, but which retained in its germ-plasm, even as the Monterey pine retained, the factors for relatively gigantic growth, biding their time and ready to make response to altered conditions of nurture.

Their opportunity came when seeds of the plant were brought from the antipodes to California, just as the opportunity of the submerged factors of the Monterey pine was found when the migration was made in the opposite direction.

AN EXAMPLE FROM THE ANIMAL WORLD

Were anyone disposed to doubt the validity of this interpretation, to question whether environment has in reality such wonderful capacity to alter the seeming mandates of heredity, evidence in substantiation may be found in quite different fields.

Take, for example, the very familiar case of the worker bee. This insect, as is well known, is an immature and sterile female. Under normal conditions in the hive, there are thousands of eggs, each like all the others, and each destined to develop into a sterile worker.

But on occasion the mature workers in the hive enlarge the cell in which one of these worker eggs is deposited, and feed the larva which hatches from it with an unusual quantity of food of exceptional richness. And the individual larva thus singled out for exceptional nurture grows and develops at a rate disproportionate to that of its fellows, and ultimately matures and becomes a fertile female, which, in the terminology of the apiary, is designated a queen.

This mature individual presently goes forth from the hive with a band of followers, and establishes a new colony. She in turn deposits eggs and becomes the mother of another swarm of drones and workers.

Yet nothing is more certain than that the hereditary potentialities of the egg which thus was transformed into a queen bee were in no wise different from the potentialities of the thousands of other eggs about it that developed only into sterile workers. Nurture alone determined the transformation. In this case it was purely a matter of food. There was no climatic change invoked or needed. Feeding alone sufficed to bring about a final development of the reproductive organs that was denied all the other larvæ of the colony.

This case of the bee is so familiar that its wonderful significance is often overlooked.

Taken by itself, it suffices to illustrate the overmastering power of nurture to decide among the conflicting hereditary tendencies that lie dormant in the germ-cell.

Lest the case seem to prove too much, however, let us not forget that it is only the eggs of the worker that through such treatment can be developed into queens. There are also in the normal hive other eggs, produced parthenogenetically, which will develop into male or drone bees, and which can by no possibilities of altered nutrition be transformed into workers or queens, any more than the worker eggs could be made to develop into drones.

But this illustration, after all, serves only to give recognition to the fundamental fact that heredity, in the last analysis, puts certain definite limitations on environmental interference.

No conceivable environing conditions can be expected, in the nature of the case, to bring out potentialities that do not exist. A dwarfed Monterey pine may be transformed through altered nurture into a mammoth pine; a dwarfed rhubarb into a giant rhubarb; a worker bee into a queen bee. But no conceivable modification of nurture could transform the Monterey pine into a rhubarb of any sort, or the rhubarb into a pine, or either pine or rhubarb into a bee.

To suggest such transformation would be grotesque. Yet these extreme cases are perhaps worth citing to emphasize the fact that when we speak of the power of nurture over nature—as applied to any given individual—we refer only to a power of selection between divergent hereditary tendencies.

The pine has become a pine through endless generations of development; the rhubarb has become a rhubarb, and the bee has become a bee, through the same slow process of evolution.

Each of these organisms, and every other specific organism of all the myriads, has its own congeries of hereditary factors, and by no conceivable influence can these be suddenly transformed.

What has been developed through the slow process of the ages can be modified through a similar slow process of future ages. Yet within each organism, by virtue of the slow development and modification through the past ages, there are stored up multitudes of hereditary factors that are more or less in antagonism, only one or another series of which can be made manifest in a given generation. And the power of environment is exercised in selecting between or among these conflicting factors.

Nurture could not determine that the Monterey pine should cease to be a pine, but it could determine whether it should be a dwarf or a giant. Nurture could transform a worker into a queen, but not into a drone.

The illustrations from the vegetable and animal worlds have been used to make the case tangible. Let us now turn attention to the human organism, and study the application of this principle to the development of the human child.

THE PRINCIPLES OF EUGENICS

When the word "eugenics" first came before the public a few years ago, there were strong ob-

A FINE SPECIMEN OF THE ROYAL WALNUT

This new Burbank variety was produced by crossing the Eastern and Western black walnuts. It grows to extraordinary size in a relatively short period. The specimen here shown is only fifteen years old.

jections to its supposed implications, on sentimental grounds.

Much of the opposition has died away in recent years, showing a very remarkable modification of public sentiment. But even now it is not unusual to hear the feasibility of any attempted application of eugenic principles challenged, on the ground that nature, having been in the business of matchmaking from time immemorial, is very well able to carry on this business without interference from the scientific students of heredity.

Such objections are reminiscent of the thought of an elder day, when the current phrase about marriage being made in heaven was taken more than half seriously, and when the entire attitude of mind of the public toward the question of the relations of the sexes was far more puritanical than it is at present.

Many causes have conspired to change public sentiment; and the very fact that the name "eugenics" has made its way so rapidly proves that the intelligent moiety of the public has become prepared to give recognition to the idea that man may conceivably exercise a directive influence in the breeding of his own race such as he has all along exercised in the breeding of the animals that he has domesticated.

The argument that nature herself is the ideal matchmaker is seen on the slightest critical inspection to be utterly fallacious; in particular since it has come to be known that hundreds of thousands of children are born into the world foredoomed to disease or to defective mentality by the mismating of their parents.

In the older conception, heredity was fatalistic. So long as it was believed that all the characteristics of a parent are transmitted to all his children, it seemed inevitable that the sins of the parents must be visited upon the children, in strict accordance with the biblical mandate. But the new knowledge of Mendelian heredity makes it clear that the hereditary factors in the germ-plasm of an individual may be potent or impotent in their tangible influence on the next generation, according to the combinations that are made with the hereditary factors of the other parent.

We have seen, for example, that factors for mental deficiency or for susceptibility to consumption, even though present in the germ-plasm of an individual, may be utterly unable to make themselves tangibly manifest if that individual mates with one in whose germ-plasm the factors for normal mentality only and for resistance to consumption are present.

Thus the mandate that seemed to condemn the offspring may in many cases be rendered nugatory by the right selection of marriage partners.

Here, then, is a specific instance in which a definite knowledge of the laws of heredity might serve to determine whether the offspring of an individual should be normal or defective; where, in a word, the principles of eugenics might be practically applied with benefit to a fraternity of individuals. And if it be objected that such an application of cold scientific principles seems to rob marriage of all romance, it is perhaps an adequate and comprehensive answer to point out, as I have been moved to do on various occasions, that there is nothing appealingly romantic about a brood of epileptic or neurotic or imbecile children.

It is possible, however, to supplement this suggestion with the assurance that, in general, the application of eugenic principles to the mating of human beings would not by any means necessitate the supplanting of the old traditional method of matchmaking, but would only serve as a supplementary procedure, aimed at the perfecting of a method which must be admitted to lack something of the ideal.

NATURE AS EUGENIST

In point of fact, it requires but the most casual knowledge of the subject to convince one that nature herself is the original eugenist, and that the motives that actuate individuals under the spell of the god of love are essentially eugenic motives.

To substantiate this suggestion, it is only necessary to call attention to the fact expressed by the common saying that opposites attract. This means that a person is drawn toward one of the opposite sex whose predominating tendencies correspond to his subordinated ones.

Note, as practical illustrations, how the tall man is attracted by the small woman, blonde by brunette, genius by mediocrity. It is even matter of common experience that the most virtuous young women are often fascinated by opposite moral traits in their male associates; while, contrariwise, the most vicious men would always choose virtuous helpmates if they could.

These propensities have long been recognized, and they have been explained as representing a tendency of nature to avoid extremes and keep near to a happy mean. It has been observed that extreme development in any direction leads to instability, and it is everywhere accepted that a well-rounded development is, on the average, preferable to a highly specialized development in one direction. But the real significance of the observed tendency of opposite physiques and temperaments to attract each other is more clearly explicable than ever before since a knowledge of Mendelian heredity has given clews to its true interpretation.

The fact seems to be that what we term Mendelian heredity represents nature's incessant attempt to improve the race.

It is an observed fact that physical strength and vigor are dominant factors; hence the offspring of a strong individual and a feeble one are likely to be strong. It is obviously desirable, then, from a eugenic standpoint, that weak individuals, if they are to mate at all, should mate with strong ones. And nature has all along provided that this should take place, through establishing the natural affinity of weak for strong and of strong for weak, just referred to.

It is matter of everyday observation that women of a masculine type are attracted to more or less effeminate men; and, contrariwise, that men of the most virile type are drawn to women who are the embodiment of femininity. And the most coldly logical student of scientific eugenics must applaud these inherent preferences.

In a word, then, it may be said that the new science of eugenics does not come forward as a revolutionary force, but only as a supplementary force. In general, the study of scientific heredity has sufficed to show the logicality of spontaneous love, rather than to suggest its illogicality. But this verdict must be modified to the extent of urging that it may be possible for the student of heredity to point out individual instances in which a scientific analysis reveals impediments to what otherwise might be a thoroughly eugenic and desirable mating.

In other words, the province of eugenics at the present stage of its development is, as has been suggested in an earlier chapter, not so much to determine whom an individual should marry as to show, on occasion, whom he or she should not marry. The definite implications and applications of this principle will appear as we proceed. A clew to them is given in the statement that eugenics is recognized as having two quite different aspects, a negative and a positive aspect.

Negative eugenics aims to prevent the birth of the unfit; positive eugenics aims to bring about the birth of the fit.

We must consider each of these subjects independently, but it may fairly be said at the outset that negative eugenics has far wider present-day application and is of more immediately practical import to our race than positive eugenics.

THE BREEDING OF THE UNFIT

It is a familiar observation everywhere to-day that the better classes of citizens as a rule have fewer children than the less desirable classes.

A striking illustration of this is furnished by some statistics recently collected by Professor Cattell, of Columbia University, showing that the families of a large number of the more distinguished scientific men in America consist, on the average, of less than two members. And this observation is fairly in accord with the general observation, according to which the members of the community that should be looked to, from a eugenic standpoint, to propagate the species are the ones who have the smallest families.

Contrariwise, it is matter of equally familiar observation that the people of the slums of our cities, the recent immigrants representing the lower orders of European population, and the defective and criminal classes, are vigorous and prolific breeders.

This, obviously, amounts to saying that increase of population is largely promoted by the less desirable, rather than by the more desirable, members of the community.

Whereas all evolutionary progress in the past has been due, we are led to believe, largely to natural selection of the fittest members of the animal and vegetable populations as the propagators of the species, mankind is now making the experiment of artificial selection, in which the survival of the unfit becomes the outstanding feature.

It is as if Mr. Burbank were to select among cross-bred plants the ones that showed the least desirable qualities, and were carefully to preserve the seed of these, destroying the seed of the more desirable members of the colony. It needs no profound knowledge of plant breeding to predict what must come to pass were this plan to be followed in the orchard or field or garden. No one will for a moment suppose that Mr. Burbank could have produced his remarkable new varieties of plants by such a method. No one doubts that the application of such a method would result in the rapid retrogression of even the best varieties, so that they would presently be represented by a degenerate progeny.

It is equally little in doubt that a breeder of thoroughbred horses, or of special varieties of dogs or chickens or pigeons, would work havoc in the ranks of his pedigreed stock were he to encourage the breeding of inferior members and restrict the breeding of superior ones.

No one doubts that the same laws of heredity apply to plants, to animals, and to the human race. How, then, can we doubt that the present customs of human society, in which the less fit members of the community are by far the most prolific, must tend to encourage racial degeneration?

Seemingly there can be no difference of opinion on this question. But serious differences arise when we proceed to the natural inquiry as to what may best be done to change the existing conditions.

The statement that it is desirable to increase the prolificness of the better classes and to restrict the fecundity of the inferior and defective classes, considered as an abstract proposition, will pass unchallenged.

But whenever the attempt is made to suggest specific means through which these ends may be attained, such suggestions are sure to be met with violent opposition.

Nevertheless, it is incumbent upon us, in the present connection, to endeavor to view the situation without sentimentality, and from the standpoint of the student of heredity.

In particular, we are called upon to make application, as best we may, of the principles of plant development that are revealed by a study of Mr. Burbank's work, in their bearing on the breeding of the human plant. And when we view the matter from this standpoint, it would appear that there are at least a few specific propositions

VARIATION AMONG THE CANES OF SEEDLING BRIARS

The key-word of Mr. Burbank's work is selection. This picture suggests the variety of material that may result from a single experiment, giving almost infinite opportunity for selection. These seedlings were produced in the course of the experiments for the development of the thornless blackberries and raspberries.

that may be urged with a fair measure of assurance.

RESTRICTING THE FECUNDITY OF THE UNFIT

First and foremost among these is the belief that the notoriously unfit members of the community, as represented by criminals, the insane, and the mentally defective, should on no account be permitted to have progeny.

These defectives represent a recessive element in the human germ-plasm. And all our modern studies make it increasingly clear how difficult it is to eliminate a recessive trait from the strains of any race of organisms. To be sure, a recessive quality disappears altogether in the first filial generation when mingled in the germ-plasm with the antagonistic and dominant quality. But it not only reappears tangibly in a certain proportion of the offspring of the second generation, but it also remains as a latent factor in the germ-plasm of two out of three of the progeny of that generation who give no outward evidence of its presence.

Such, it will be recalled, is the characteristic feature of Mendelian inheritance, and when we consider the facts from the present point of view, it might fairly be questioned whether the terms dominant and recessive might not better have been reversed. It is far easier to fix a recessive quality, because its tangible manifestation proves the absence of the corresponding dominant factors. But we have no way of telling that any organism showing a dominant quality does not carry the opposite recessive factors dormant in its germ-plasm.

So far as we can judge, there is no limit to the number of generations through which the factors for a recessive quality may be conveyed in a state of latency or impotence, and yet may become active and make themselves manifest through a chance mingling with germ-plasm conveying similar recessive factors in the same state of latency.

If I correctly understand the matter, recessive characters are characters that are relatively old in the evolutionary sense, and dominant characters are those that are relatively new. In each and every case where antagonistic qualities are matched against each other there is reason to believe that the newer character will tend to manifest the phenomena of dominance, and the older character the phenomena of recessiveness.[1]

The entire Mendelian formula might be said to express nature's receptiveness toward innovation, on one hand, and her tendency to hold fast to that which has been proved good, on the other hand.

An organism that has acquired a new char-

[1] Perhaps it should be explained that this interpretation of the underlying nature of the phenomena of dominance and recessiveness is original with the writer. It is based on a rather wide study of the phenomena of Mendelian heredity in both vegetable and animal worlds. It exactly reverses the explanation that has been suggested by some other biologists, but the writer believes that it is the most plausible interpretation of the phenomena in question hitherto suggested. The basis for this belief will be elsewhere set forth in detail.

acter mates with an organism in which the same character is of an older type. The progeny all give outward manifestation of the new character. But their progeny show the recurrence of the old character in one case in four, and two other members of the four carry the factors for this quality as a recessive element in their germ-plasm. If the new character is beneficial to the species, the individuals showing it (who in the second generation, it will be recalled, outnumbered their fellows of the same fraternity three to one) will thrive and propagate their kind, and the individuals having the new quality will increase rapidly in number.

But meantime there is always a possibility that the new character may be beneficial only under local conditions or for a limited period; so nature is by no means minded to renounce the old character all at once. Generation after generation, she provides that the factors for the recessive traits shall be carried forward, and that a certain proportion of the individuals of each generation shall be "mixed dominants," whose offspring will have representatives showing the old character. So even when the new character is a highly beneficial one, the old character still tends to recur and to fight for recognition.

But if, on the other hand, the new character is one that is not beneficial, the individuals that show it are quickly weeded out, and only the recessive members of the fraternity remain. In other words, a new or dominant character must be advantageous to its possessor—or at all events not detrimental—or it is quickly eliminated, because there is no such thing as the carrying forward of this character as a latent element in the germ-plasm. But the old and therefore recessive character may be carried forward in the germ-plasm generation after generation, for the very reason that it is not outwardly manifested, and therefore does not handicap the individual in whose germ-plasm it rests.

Now we have seen that certain notable defects of the human organism, which are manifested in mental deficiency or insanity, act as recessive traits in inheritance. The same thing is true of the allied defects that are the foundation of criminality. We are led to infer, then, that these conditions of mental and moral obliquity represent earlier stages of human evolution. The individuals who manifest these defects in any given generation are those whose ancestors have mated in such an unfortunate way as to preserve the recessive character either as a patent or a latent factor in their germ-plasm. In effect, the mentally and morally deficient classes of to-day belong to a remote generation of the past. The hereditary factors that are responsible for their mental equipment have come down unchanged from remote ancestors who lived under conditions of barbarism in which the traits that we now describe as aberrant or defective were a part of the normal equipment of the race.

In the long stretch of intervening generations, new traits have been developed and old traits modified, but these traits, which represent the higher attributes of our mental and moral natures, while they have proved dominant to the older barbaric traits, have not been able to eliminate the old traits altogether from the germ-plasm of the race. So now and again there appears an individual in which the recessive traits are patent; and it merely evidences the force of the laws of Mendelian heredity with which we have become familiar to note that these recessive individuals breed true to their recessive quality of mental and moral deficiency.

Theoretically, we should expect that when two of these recessives are mated, their offspring would be recessives.

And the observations of the alienists and criminologists in recent years prove the correctness of the preconception. When two mental defectives are mated, their offspring are all defectives. Of course we can momentarily submerge the defective strain by mating the recessive individual with a normal individual. But the progeny all carry, submerged in their germ-plasm, the recessive factors. Even though themselves outwardly normal, they represent tainted stock, and the taint will make itself manifest sooner or later in their progeny.[1]

[1] The question may arise as why genius may also act as a recessive trait, as previously pointed out. The answer is that the type of genius that may so operate in heredity is the unstable of ill-balanced type allied to insanity, and owing its success largely

Logically, then, there would seem to be no reason why such tainting of a stock should be knowingly permitted. There would seem to be no reason why a recessive individual of this type should be permitted to vitiate the germ-plasm of the race. So long as the recessive quality is latent, we can do nothing directly to eliminate it; but when it becomes patent in an individual case, opportunity is afforded to dam back permanently that particular stream of recessive germ-plasm.

And the way in which this can be effected, obviously, is by sterilization of the individual who manifests the defect.

Still holding to the biological point of view, there would seem to be no question that a proper regard for the welfare of future generations demands that all mentally and morally defective individuals of unequivocal type should be sterilized. The rule should apply, it would seem, to all subnormal children; to the insane of every type; and to all persons whose lack of moral control is such as to have led them to commit infractions of the social order that rank as felonies.

So comprehensive a programme for the elimination of recessive germinal factors for mental and moral traits will doubtless seem little less than appalling to many readers. But there seems

to the presence of an elemental egoism and excessive energy that are primordial traits. Stable genius probably tends to be dominant in heredity. The offspring of men of large and stable mental endowment are usually able. The sons of Charles Darwin may be cited in illustration.

no escape from the conclusion that such a restrictive programme would be of enormous benefit to the coming generations. The lessons of heredity are futile unless we are prepared to act upon them. And there is no reason why action should stop with halfway measures in regard to the classes just named. The imbecile, the insane person, and the criminal are undesirable progenitors of members of a civilized community. In the interests of the community they should be scientifically restrained from incurring the obligations of parenthood.

That, seemingly, is the first and perhaps the most unequivocal lesson in negative eugenics that may be drawn from the modern studies of heredity.

THE QUESTION OF RESTRICTING MARRIAGES

When we turn to the other aspect of the subject that has been most widely exploited—the question, namely, of putting legal restrictions on the marriage of persons suffering from various diseases—we find ourselves on much more debatable ground.

Some rather plausible laws have been put on the statute books of various states in the past two or three years, making it obligatory for persons seeking a marriage license to show a medical certificate giving them a clean bill of health with regard to one or two transmissible diseases. The purpose of such laws is obviously commendable, but it may seriously be doubted whether public opinion has yet been educated to the point where it will give the laws adequate support. We have advanced a long way in recent years, but there is still a large measure of reticence regarding the discussion of topics directly involved in measures of this character. The futility of attempting to prevent the union of young persons who have decided to marry is matter of common knowledge.

Moreover, a really comprehensive law that prevented the marriage of all incompetents would fail of its ultimate object, in that it would mainly result in substituting illegitimate children for legitimate ones.

As regards the commendable attempt to restrict the dissemination of venereal diseases, which is the essential motive of the laws just cited, it seems probable that this end would be more advantageously effected by comprehensive sanitary laws placing all venereal diseases on a par with other contagious maladies; requiring all cases of such diseases to be reported to the health boards, and inflicting severe penalties on all persons who knowingly transmit these diseases.

Such a sanitary code would obviously be difficult of carrying out, but the great strides that public hygiene has made in recent years warrant the hope that such measures as those just suggested will before long be thought worthy of trial everywhere. It seems more logical to endeavor to stamp out these virulently contagious and heritable maladies at their source than merely to attempt to guard a single avenue among many through which they may be transmitted.

Nevertheless, the placing on the statute books of several states of laws of the character just noted may be taken as marking a very notable stage in the progress of the eugenic propaganda.

POSITIVE EUGENICS

All the measures thus far suggested obviously look to the restriction of the breeding of the unfit, and leave quite untouched the converse side of the problem—namely, the stimulation of the reproductive activities of the fit. But we have already called attention to the familiar fact that there is a great dearth of children among precisely the classes who are best adapted, through heredity and through the environment that their homes supply, to furnish desirable citizens of the next generation.

It is obvious, however, that any attempt to regulate the size of the families of the better classes of society lies far beyond the bounds of present-day legislation. The time may come when special bonuses will be offered in the way of exemption from taxation or direct government subsidy for large families. Such an expedient is not without historical precedent. But it may safely be predicted that if it should ever seem necessary to resort to so extreme a measure in any civilized community of the future, the provision will not be indiscriminate in its application, but will apply to a restricted portion of the community, the favored couples being such as adequately meet conditions imposed by a eugenic board having a fuller knowledge of heredity, perhaps, than anyone at present possesses.

Materials for such enhanced knowledge are being gathered, however, by the Eugenics Record Office at Cold Spring Harbor, and it is within the possibilities that enough family genealogies, collated from a new point of view, will be available in the course of another decade or two to give data for a new type of pedigreed-stock book, of which human beings will be the subjects.

Such a suggestion probably seems grotesque to the average reader; even to the reader who has gained a certain inkling of the laws of heredity. Yet a serious consideration of the facts as to the increase of population in recent decades, coupled with reflections on the *character* of the increase, justifies the prediction that legislative measures based on such knowledge will furnish the basis for marriage customs that will become a matter of everyday routine in the not very distant future.

We hear much clamor about race suicide; and when a nation like France fails to increase in population as rapidly as its neighbors, the wiseacres shake their heads and talk about national degeneracy. Yet it is known that the population of Christendom has doubled in the past half-century, and it is a matter of the simplest computation to show that if this rate of increase were to continue there would not be standing room in the world for the human population in the year 4000 A.D. If the population of the United States were to increase as rapidly in the coming century as it has in the past century, starvation would stare the main body of our great-grandchildren in the face.

In a word, the great menace of the moment is not race suicide but race repletion.

And, as we have seen, it is the less desirable members of the race who are most prolific. Hence the human garden is in danger of being choked with human weeds. There is eminent need of cultivation akin to that which Mr. Burbank practices when he would improve a race of plants instead of allowing them to run wild and deteriorate.

Yet, as I said before, it must be admitted that at the present stage of social development no very definite remedies, on the side of positive eugenics, can be suggested as capable of immediate application. The most that can be hoped, perhaps, is that knowledge of the laws of heredity may be spread broadcast, until the average intelligent citizen is sufficiently informed to have logical opinions on this most important topic. When the time comes that a larger number of cultivated men and women have as comprehensive a knowledge of heredity as is now possessed by a small number of breeders of plants and special types of domesticated animals, and when the public at large realizes that the same laws of heredity apply to man as to all his fellow-beings, we shall be prepared to consider the possibility of measures looking to the betterment of the human breed through conscious direction of a character not very different from that which has resulted in the development of specialized races of horses and cattle and others of man's confrères.

Incidentally, we may add that it is largely with the thought of aiding in the promulgation of knowledge that must underlie such an advance that the present chapters are included in this book.

THE PROVINCE OF EUTHENICS

In the meantime, it fortunately chances that the obverse side of the question of breeding a better race can be considered with far less infringement on the prejudices of mankind in general; partly because the questions involved are not at first thought recognized as having eugenic significance. Reference is made, of course, to the active movements of recent years in the way of bettering the environment of the individuals and the communities of our generation. The work that has already been accomplished in this regard is little less than revolutionary. Its effects must be strikingly manifest on the coming generations.

It is unnecessary here to refer, except in the most general way, to the sanitary reforms in question. Everyone knows something of the enheartening story of how light is being let into the dark tenement dwellings of our cities; how sanitary guard is now kept over the food supplies, including in particular the all-essential milk supply; how preventive medicine has learned to guard our ports against the invasion of plagues and to minimize the spread of the contagious maladies by warring upon the mosquitoes and flies and rats that serve as germ-carriers.

It is familiar knowledge, also, that medical science has found means to treat individuals suffering from contagious maladies, and in particular to give immunity to others through serum and vaccine treatments, the discovery of which has resulted from the new knowledge of bacteriology.

All in all, the work of preventive medicine has been so effectively carried forward that the death rate in our cities has decreased, particularly as it concerns the infant population, to a fraction of what it was. The average age of mankind has been practically doubled since the time of our grandparents.

All this is matter for just pride and enthusiasm to the humanitarian. Yet from the standpoint of the eugenist, it appears that these triumphs of preventive medicine do not represent an altogether unmixed blessing. Looked at with a coldly analytical eye, it appears that the preservation of weakly infants through what may be likened to a hothouse cultivation must enhance the number of adult members of the population of the coming decades who are peculiarly unfit to propagate the species.

In other words, it would appear that the first notable result of the recent betterment in the practice of euthenics must be to complicate the problem of the eugenist.

From the present standpoint, we could hardly fail to recall that the work of the modern hygienist is directly in opposition to the method that Mr. Burbank has so persistently practiced at Santa Rosa in dealing with the weakly and susceptible members of his plant colonies.

From the outset, the theory on which he has worked, and worked to such advantage, has been that the best protection to his plant charges against the disease with which they are menaced must come from within the constitution of the plants themselves. So he has sought to develop immune races. He has not been sedulous to find remedies for plant diseases, and he has almost totally avoided the use of sprays and medicants to kill off the fungous and bacterial enemies. His habit has been to check disease by weeding out and destroying the seedlings that showed susceptibility to disease.

The hardy individuals that remain owe their preservation to the fact that their tissues were able to fight off the inimical germs; and it was observed that such immunity is a heritable trait, so that the individuals possessing it become the parents of an immune race.

It might seem, then, that the method of the modern hygienist is a direct contravention of the method which the plant developer has found advantageous. A strict application of Mr. Burbank's method to the human plant would suggest that we lessen rather than increase the safeguards against bacterial foes that surround the average child. The individual that is susceptible should, in this view, be permitted to succumb, in the interest of the race.

Of course, no humanitarian can give assent to such a literal application of the knowledge of the plant breeder. Mr. Burbank himself would be the last to suggest such an application. We must recall that the aggregate conditions of civilization are artificial in the highest degree; that civilized man is and must everywhere remain a hothouse plant. The essential province of government is to give the weak protection against the strong, and against the adverse forces of nature.

The manners and customs of civilized society have been built up in recognition of the fact that persons weak-bodied and susceptible to disease may have attributes of mind that make them among the most valuable members of society.

Civilized man is not reared to compete with the denizens of the jungle, nor to submit to the hardships that may fall to the lot of barbaric tribes. His case is rather that of the tropical plant transported to temperate zones, which may require the constant protection of a hothouse environment, being quite unable to compete with plants of the field, yet being prized for the flowers that it puts forth, and regarded as fully worth the solicitous care necessarily bestowed upon it.

Viewed in this light, the work of the euthenist who seeks to better the environment of the race takes on a quite different aspect. The physical weakling that is saved from an early demise only by a pampering environment may prove an intellectual giant—a Newton, a Darwin, a Spencer—of greater benefit to the world than any conceivable number of physical giants.

In a word, the fact that man is essentially an intellectual animal must be borne in mind at all stages of consideration of the problems of the eugenist.

Yet the fact remains that the intellect of man is bound up with his physical organization; and it would be absurd to deny that the problem of the eugenist is primarily a physical one, even though it deals also with the mental organization. The ideal man must be sound of body as well as sound of mind; and the ultimate problem of the eugenist is, how to give us a race of human beings which shall combine in the fullest measure physical vigor and mental vigor. "A sound mind in a sound body," was the familiar maxim of the ancient Greeks; and it represents no less fully the ideal of the eugenist of to-day.

If the work of the euthenist preserves a certain number of weaklings who might perhaps, in a coldly critical view, be regarded as undesirables, it preserves also thousands of children who will grow into robust and vigorous adults. We have already suggested that even those who remained physical weaklings may have mental qualities that far outbalance their physical defects. Such physical weaklings with wonderful brains may have their strains blended with the strains of other individuals of robust physique, with the result of developing progeny showing an ideal blending of physical and mental qualities.

So in the last analysis it appears that the work of the euthenist is in fullest harmony with that of the eugenist.

Or, better stated, euthenics is but an aspect of the larger problems of eugenics. The ultimate object at which they both aim is the development of a race of human beings representing as close an approximation as may be to physical and mental perfection.

And when we add that such ideal personalities command the instinctive admiration of mankind in general (witness the universally applauded heroes and heroines of stage and story), it requires no further argument to show that in their ultimate influence eugenics, euthenics, and normal love between the sexes are linked in a triumvirate at once harmonious and beneficent.

THE END

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